ENGINEERING FIELD MANUAL

CHAPTER 11. PONDS AND RESERVOIRS

Compiled by: George M. Renfro, Agricultural Engineer, SCS, Fort Worth, Tex.

Contents

PART I - GENERAL

PART II - EMBANKMENT PONDS

Page

Tables

Exhibits

CHAPTER 11. PONDS AND RESERVOIRS

PART I - GENERAL

1. DEFINITION

Ponds and reservoirs are bodies of water created by constructing a dam or embankment across a watercourse or by excavating a pit or dugout. Ponds constructed by the first of these methods are referred to hereinafter as "Embankment Ponds" and those constructed by the latter method as "Excavated Ponds." Ponds resulting from both excavation and embankment are classified as Embankment Ponds where the depth of water impounded against the embankment at emergency spillway elevation is 3 feet or more.

2. USES FOR WATER ON THE FARM

WATER FOR LIVESTOCK

Water is as important as forage in the production of livestock. Inadequate stock water developments in pasture and range areas contribute to an unstable livestock industry and livestock losses, prevent use of needed grazing areas, and encourage overgrazing in the vicinity of existing water supplies.

Providing adequate water for livestock on range and pasture consists of developing enough water to satisfy stock needs and providing a proper distribution in relation to the available forage.

A pond should be of a size that will meet the needs of all livestock that will use the surrounding grazing area. Table 11-1, showing the average daily consumption of water by various kinds of lifestock, should be helpful in estimating water needs.

Table 11-1. Daily consumption of water by livestock

Kind of Livestock	Gallons per Head per Day
Beef Cattle and Horses	12-15
Dairy Cows (drinking only)	15
Dairy Cows (drinking and barn needs)	35
Hogs	4
Sheep	2

The total amount of water that will be consumed at one pond will depend on the average daily consumption per animal, the number of livestock served, and the length of period over which they are served.

IRRIGATION STORAGE

The required storage capacity of a farm reservoir used for irrigation depends on a number of factors. These are the water requirements of the crops to be irrigated, the effective rainfall that can be expected during the growing season, the application efficiency of the irrigation method used, the losses due to evaporation and seepage, and the expected inflow into the pond. All of these can be estimated with reasonable accuracy and a water budget prepared to determine the required capacity of the reservoir.

Where the acreages to be irrigated and the storage requirements are small, the preparation of water budgets is often not justified. In such cases, Table 11-2, or locally developed guides, can be used to determine storage requirements in small irrigation ponds and reservoirs.

Table 11-2. Capacity guide for small irrigation reservoirs 1/

Climate	Annual Rainfall Inches	Acre Feet per Acre Irrigated 2/		
		Vegetable Crops	Field Crops	Perennial Crops
Superhumid	Over 60	0.75	1.00	1.25
Humid	40 - 60	1.00	1.50	1.75
Subhumid - Moist	30 - 40	1.50	2.00	2.50
Subhumid - Dry	20 - 30	2.00	2.75	3.50
Semiarid	10 - 20	3.00	4.00	6.00
Arid	Under 10	Small reservoirs are not reliable		

1/ Based on the assumption that the watershed area is adequate to fill the reservoir at least once annually.

2/ Table is limited in use to 40 acres irrigated.

Where irrigated acreages are large the preparation of a water budget is required. In such cases the problem should be referred to an experienced engineer or hydrologist.

REGULATION OF IRRIGATION STREAMS

In some locations available irrigation streams fluctuate widely or become so small as to limit the method of application, reduce the efficiency of application, or require excessive amounts of labor. In such instances, on-farm regulating or "overnight storage" reservoirs may be constructed to regulate and increase the available irrigation stream. Reservoirs are filled by canal delivery, diversion, or pumping.

The regulating reservoir should be located where it will serve the largest acreage possible consistent with the available water supply. The capacity of such a reservoir will vary with the stream size to be regulated and the period of time it is to be stored. Storage of the available inflow for 24 to 72 hours is common.

FIELD AND ORCHARD SPRAYING

Ponds may provide water for applying insecticides and fungicides to field and orchard crops. The amount of water needed for spraying is relatively small, but it is important that it be available when needed. About 100 gallons per acre for each application should be enough for most field crops. Orchards, however, may require 1,000 gallons or more per acre for each spraying.

Suitable means should be provided to convey water from the pond to the spray tank. If the pond is of the embankment type, a pipe placed in the dam and equipped with a valve and a flexible hose at the downstream end will permit the spray tank to be filled by gravity. If the pond is the excavated type, a small pump will be required to fill the tank.

FISH PRODUCTION

A pond that is constructed and managed properly may yield from 100 to 300 pounds of fish annually for each acre of water surface. This is about equal to the beef production realized from average improved grassland.

Ponds with a surface of 1/4 acre to several acres can be managed for good fish production. Those less than two acres have proven popular since they are not as difficult to manage as the larger ones.

Shallow water at the edges of a pond promotes waterweed growth, which makes fish management difficult, and provides a breeding place for mosquitoes. These problems can be overcome to a large extent by deepening the shallow edges around the pond. This can be done by borrowing from the pool edge during construction, or by cutting and filling as shown in Figure 11-1.

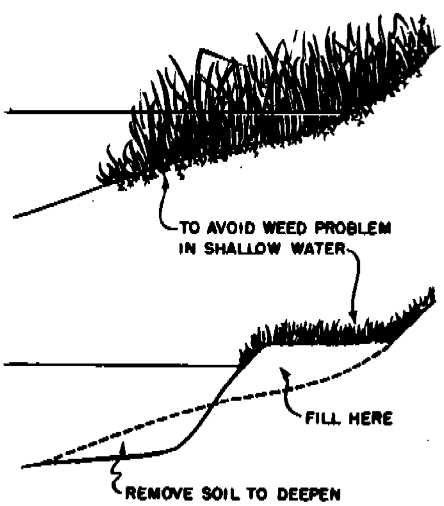


Figure 11–1 Deepening pond edges by cut and fill method

FIRE PROTECTION

The fire protection pond should be located reasonably near the buildings to be protected. A centrifugal pump with power unit attached and a length of hose sufficient to reach all sides of the farthest building should be provided. It is good practice in areas subject to freezing to provide for one or more dry hydrants similar to the one shown in Figure 11-2.

A satisfactory fire stream should not be less than 250 gallons per minute with a pressure at the nozzle of no less than 50 pounds per square inch. Fire nozzles usually range from 1 to 1½ inches in diameter. Good quality rubber-lined fire hose, 2½ to 3 inches in diameter, should be used. The length of the hose should preferably not exceed 600 feet.

A typical example of a fire hose line is one consisting of 500 feet of 3-inch hose to which a 1-1/8-inch smooth nozzle is attached. A centrifugal pump, operated at 85 p.s.i. will provide a stream of 265 g.p.m. with a nozzle pressure of 50 p.s.i. Such a stream running for 5 hours would require 1/4 acre foot of water. Local dealers in pumps, engines, and similar equipment should be able to furnish the data required regarding pump capacities and engine horsepower.

A fire protection pond may also serve as a source of supply for local fire departments when accessible to large tank trucks. These trucks are heavy with a maximum capacity of about 1,000 gallons. They normally carry about 20 feet of suction hose and generally must operate from all-weather roads. These points should be considered in location of dry hydrants. When used for this purpose, hydrant fittings should be designed to fit local fire company equipment. To make best use of these installations the fire department should be kept up to date on the location of installations accessible to their equipment.

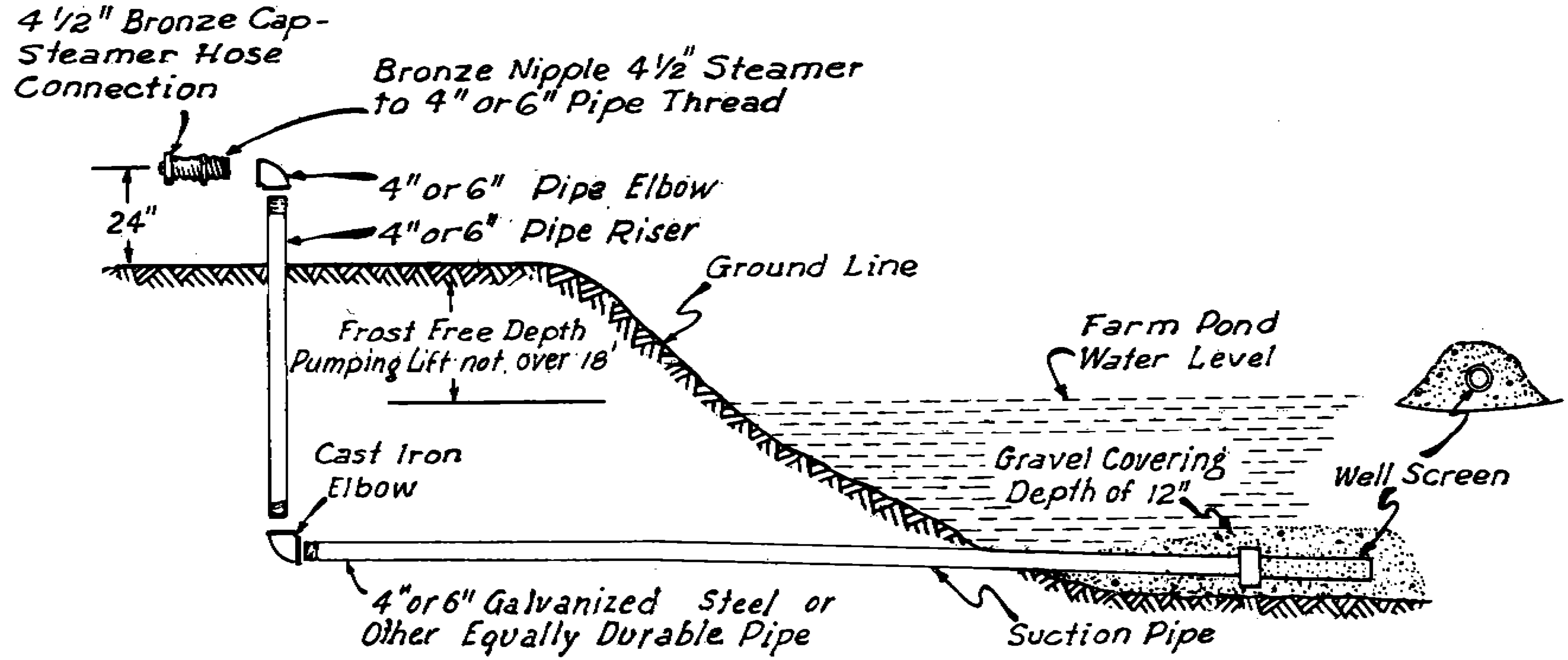
RECREATION

A pond or reservoir can provide recreation, such as swimming, boating and fishing for the owner, his family, and friends. The area immediately surrounding the pond can be made into an attractive place for picnics and games.

Where a pond is used for public recreation, there should be a supply of water adequate to overcome evaporation and seepage losses and maintain a desirable water level. The waters must be free of pollution, especially where they are used for swimming and bathing. If bathing is one of the intended activities there should be an adequate depth of water in the vicinity of a gently sloping shore. Minimum facilities for public use and safety, such as access roads, parking areas, boat ramps or docks, fireplaces, picnic tables, and drinking and sanitary facilities, should be provided.

For protection of the public health, most states have laws and regulations governing water supplies being used for such purposes as bathing and human consumption to meet certain prescribed standards. Such supplies usually must be tested and approved before their use by the public is permitted.

4-20467 Rev. 12-68



(Not to scale)

Figure 11–2 Details of dry hydrant installation.

WATERFOWL AND OTHER WILDLIFE

Ponds and reservoirs attract many kinds of wildlife. Migratory waterfowl often use them as resting places in their flight to and from the North. In some of the northern states ducks often use them as breeding places, particularly where there is an ample supply of good food. Upland game and game birds use ponds as watering places.

MULTIPLE USES

Where possible, a pond should be constructed to provide water for two or more purposes. For example, it could be used to provide water for livestock, for fish production and for spraying one or more field crops. Storage requirements for each purpose should be considered to be sure of an adequate supply for all intended uses.

The several purposes for which water is to be used should be compatible. Some combinations are not. For example, a pond would not normally be used for both irrigation and recreation. Unless the reservoir is very large, most of the water might be removed during the irrigation season, thereby lowering the water level to a point where boating and swimming would not be practical.

LEGAL REQUIREMENTS

Many states have laws that require permits to construct dams for water storage for any intended use. The technician should know the requirements in his state and comply with them in the planning, design, and layout of ponds and reservoirs.

3. TYPES OF PONDS AND RESERVOIRS

Farm ponds and reservoirs may be divided into two general types; namely, embankment and excavated ponds. An embankment pond is a body of water created by constructing a dam across a stream or watercourse. These ponds usually are built in areas where land slopes range from gentle to moderately steep and where stream valleys are sufficiently depressed to permit the storage of water to a considerable depth.

An excavated pond is a body of water created by excavating a pit or dugout. These usually are constructed in relatively level areas. The fact that their capacity is obtained almost entirely by excavation limits their use to locations where only a small supply of water is required.

Ponds are also built in gentle to moderately sloping areas where capacity is obtained by both excavation and the construction of a dam. For the purpose of classification, these are considered to be embankment-type ponds if the depth of water impounded against the embankment exceeds three feet.

4. SELECTING THE POND SITE

The selection of a suitable pond site should begin with preliminary studies of possible sites. Where more than one site is available, each should be studied separately with a view of selecting the one that proves most practical and economical.

From an economic viewpoint, a pond should be located where the largest storage volume can be obtained with the least amount of earthfill. This condition generally will occur at a site where the valley is narrow, side slopes are relatively steep, and the slope of the valley floor will permit a large deep basin. Such sites tend to minimize the area of shallow water; however, they should be examined carefully for adverse geologic conditions. Except where the pond is to be used for wildlife, large areas of shallow water should be avoided due to excessive evaporation losses and the growth of noxious aquatic plants.

Ponds to be used for watering livestock should be spaced so that livestock will not have to travel more than one-quarter mile to reach them in rough, broken country, nor more than one mile in smooth, relatively level areas. Forcing livestock to travel long distances for water is detrimental to both the livestock and the grazing area. Overgrazing near water and unused feed far from water are characteristic of inadequate water distribution.

Where water must be conveyed for use elsewhere, such as for irrigation or fire protection, ponds should be located as close to the point of use as is practical.

Ponds to be used for fishing, boating, swimming and other forms of recreation should be readily accessible by automobile. This is particularly true where the general public is charged a fee for use of the pond. The success of such an income-producing enterprise may well depend on the accessibility of the pond.

Pollution of farm pond water should be avoided by selecting a site where drainage from farmsteads, feeding lots, corrals, sewage lines, mine dumps and similar areas will not reach the ponds. Where this cannot be done practically, the drainage from such areas should be diverted from the pond.

The pond should not be located where sudden release of the water, due to failure of the dam, would result in loss of life, injury to persons or livestock, damage to residences or industrial buildings, railroads or highways, or cause interruption of use or service of public utilities. Where the only suitable site presents one or more of these hazards, a more detailed investigation should be made.

Low-hanging powerlines present a hazard to fishermen and others using farm ponds. They may be within reach of a fishing rod held by someone fishing from the top of the dam. Sites under such lines should be avoided.

A check should be made to insure that no buried pipelines or cables exist in the construction area. These might be broken or punctured by the excavating equipment, resulting not only in damage to the utility but in injury to the operator of the equipment as well. Where such a site must be used, the utility owners should be contacted prior to foundation investigation or construction.

5. PRELIMINARY SITE STUDIES

In addition to the considerations mentioned for the selection of a pond location, there are other physical characteristics of the drainage area and the pond site which should be investigated before the final selection is made.

ADEQUACY OF THE DRAINAGE AREA

Where surface runoff is the main source of water supply, the contributing drainage area should be large enough to yield sufficient runoff to maintain the water supply in the pond during all periods of intended use. The drainage area should not be so large, however, as to require large and expensive overflow structures to bypass runoff safely.

The amount of runoff that can be expected annually from a watershed of a given area depends on so many factors that no set rule can be given for its determination. The physical characteristics of the watershed that have a direct effect on the yield of water are land slopes, soil infiltration, vegetal cover and surface storage. Storm characteristics such as the amount, intensity and duration of rainfall also affect water yield. All of these characteristics vary widely throughout the United States.

Exhibit 11-1 can be used as a general guide for estimating the size of a watershed required for each acre-foot of capacity in a pond or reservoir to maintain normal pool level, if more precise local data is not available. The map does not apply when ponds are used for irrigation.

MINIMUM POND DEPTH

For a permanent water supply, it is necessary to provide sufficient water depth to meet the intended use and to offset seepage and evaporation losses. These losses vary in different sections of the country and also from year to year in any section. Table 11-3 shows recommended minimum depths of water for farm ponds, assuming normal seepage and evaporation losses. Greater depths are desirable where a year-round water supply is essential or where seepage losses may exceed three inches per month. See State Standards and Specifications for local minimum depths.

Table 11-3. Recommended minimum depths of ponds and reservoirs

Climate	Annual Rainfall (inches)	Minimum Water Depth Over 25 percent of the Area (feet)
Superhumid	Over 60	6
Humid	40 - 60	8
Subhumid - Moist	30 - 40	9
Subhumid - Dry	20 - 30	10
Semiarid	10 - 20	12
Arid	Under 10	14

DRAINAGE AREA PROTECTION

To maintain the required depth and capacity of a farm pond, it is necessary that the inflow be reasonably free from sediment. The best protection is adequate erosion control on the contributing drainage area. Land under a cover of permanent vegetation, such as trees or grasses, makes the most desirable drainage area. If such an area is not available, cultivated areas that are protected by necessary conservation practices, such as terracing, contour tillage, strip-cropping, conservation cropping systems, vegetated desilting areas, and other soil-improvement practices, may be utilized as a last resort. Allowance should be made for the expected sedimentation during the effective life of the structure.

ADEQUACY OF POND CAPACITY

To insure that the water stored in a farm pond will be adequate to satisfy the intended uses, a reasonable estimate of the pond capacity should be made. The following is a simple method of estimating capacity.

The pond-full water elevation is established and the waterline is staked at this elevation. The widths of the valley at this elevation are measured at regular intervals and these measurements are used to compute the pond-full surface area in acres. The surface area is multiplied by 0.40 times the maximum water depth at the dam. For example, a pond with a surface area of 3.2 acres and a depth of 12.5 feet at the dam would have an approximate capacity of 0.4 x 12.5 x 3.2 = 16.0 ac.ft. (1 acre-foot = 325,857 gallons). If a more accurate answer is required, the surface area at successive intervals of elevation may be determined and the average end-area method may be used to compute the volume.

6. ENGINEERING SURVEYS

Once the location of the pond or reservoir has been determined, sufficient engineering surveys should be made so that the dam, spillway and other features of the pond can be planned.

Surveys for embankment-type ponds normally will consist of a profile of the centerline of the dam, a profile of the centerline of the earth spillway, and sufficient measurements for estimating the pond capacity. For the larger and more complex reservoirs, particularly those used to store water for irrigation, a complete topographic survey of the entire pond site and cross-section surveys of embankment and spillway locations may be required.

The profile along the centerline of the proposed dam should extend up both sides of the valley above the expected elevation of the top of the dam and beyond the probable location of the earth spillway. The profile should show ground surface elevations at all significant changes in the ground slope and at intervals no greater than 50 feet. The profile assists in establishing critical elevations for the structure including normal pool, crest of the emergency spillway and top of the embankment. It is used also to compute the volume of earth required to construct the dam.

A similar profile should be run along the centerline of the earth spillway from a point on the upstream end, well below the selected normal water surface elevation, to a point on the downstream end where water can be safely discharged without damage to the structure. This profile serves as a basis for determining the slope and dimensions of the spillway.

All surveys made at the pond site should be tied to reference points and a bench mark. These may be a large spike driven into a tree, an iron rod driven flush with the ground, a point on the concrete headwall of a culvert, or any other object so located that it can be expected to remain undisturbed until construction of the dam has been completed. Figure 11-3 shows a sample set of notes for a farm pond design survey.

Engineering surveys for excavated ponds are relatively simple where no water is stored against an embankment. Usually the four corners of the proposed excavation are located on the ground and rod readings taken at these points. These readings should be referenced to a bench mark and recorded. Engineering surveys for both embankment and excavated ponds may be recorded on approved standard forms or data sheets.

W. J. Sprinkle - Pond Design Survey | J. Scruggs ⊼ R. Bishop ⌀ 6-17-63 | 1

Sta.	B. S.	H. I.	F. S.	Elev.		
	Profile ℄ of Embankment					
BM 1	3.26	43.26		40.00		Nail in root 30" Oak 140' N.W. of N
0+00			3.7	39.6	Hub Stake	end of dam.
+35			6.3	37.0		
+68			10.6	32.7		
T. P. 1.	0.47	31.42	12.31	30.95		
1+00			5.5	25.9		
+37			9.9	21.5		
+53			11.4	20.0		
+75			11.6	19.8		
2+00			11.9	19.5		
+19			11.1	20.3		
+32			11.1	20.3		12.3
+36			12.6	18.8		19.9 / 50 bottom outlet channel
+40			13.2	18.2		℄ of existing stream channel.
+43			12.9	18.5		
+46			11.8	19.6		
+59			11.6	19.8		
3+00			10.6	20.8		
+35			3.7	27.7		
TP 2	10.97	42.10	0.29	31.13		
+60			10.5	31.6		
4+00			6.7	35.4		

W. J. Sprinkle - Pond Design Survey | 2

Sta.	B. S.	H. I.	F. S.	Elev.		
		42.10				
4+20			6.6	35.5		℄ proposed earth spillway
+60			6.1	36.0		
5+00			6.1	36.0	Hub Stake	
	Profile ℄ Earth Spillway					
0+00			14.1	28.0		
+27			11.4	30.7		
+48			9.5	32.6		
+70			7.7	34.4		
1+30			6.6	35.5		
+50			6.6	35.5		℄ of Embankment (extended)
+85			6.8	35.3		
2+25			8.4	33.7		
+50			10.2	31.9		
TP 3	0.64	32.12	10.62	31.48		
3+00			4.1	28.0		
+50			8.2	23.9		
4+00			11.5	20.6		
TP 4	12.62	43.96	0.78	31.34		
BM 1			3.96	40.00	Check	

Figure 11–3 Sample notes for a pond design survey.

PART II - EMBANKMENT PONDS

1. GEOLOGIC INVESTIGATIONS

SOILS IN THE PONDED AREA

The suitability of a pond site depends on the ability of the soils in the reservoir area to hold water. The soil profile should contain a layer of material that is sufficiently impervious and thick to prevent high seepage losses. Clays and silty clays are excellent materials for this purpose. Sandy clays usually are satisfactory. Coarse textured sands and sand-gravel mixtures are highly pervious and therefore are generally unsuitable. The absence of a layer of relatively impervious material over a portion or portions of the ponded area does not necessarily mean that the site must be abandoned. It usually means, however, that these portions of the area will have to be treated by one of the several methods described later in this chapter under the heading, Sealing Farm Ponds. Any of these methods may prove to be expensive.

In some areas, such as coastal plains, lake plains, and river deltas, it is often possible to impound a limited depth of water over areas where no impervious layer exists in the soil profile but where a permanently high water table exists at or near the ground surface.

Some of the limestone areas are especially hazardous for use as pond sites. There may be crevices, sinks, caverns or channels in the limestone below the soil mantle and not visible from the surface. These may drain the pond in a short time. In addition, the soils in these areas are often granular. The granules do not break down readily in water and the soils remain highly permeable. Without extensive investigations and laboratory tests, it is difficult to recognize all of the factors that might make a limestone site undesirable. One of the best guides to the suitability of a site in such areas is the degree of success experienced with farm ponds in the immediate vicinity.

Borings or test pits should be made at intervals in the reservoir area to determine the nature of the soil profile. The frequency of these borings will depend on the occurrence of significant changes in the soil profile. The borings should be made to a depth sufficient to identify the underlying materials that may affect the design or safety of the structure. A record, or log, of each boring or test pit should be made showing the location, depth and classes of materials encountered. The location of each boring should be marked on the ground so it can be referenced to other or more detailed surveys.

STUDIES OF FOUNDATION CONDITIONS

The term foundation, as used here, includes the valley floor and its side slopes, or abutments. The requirements of a foundation for an earthfill dam are that it provide stable support for the embankment under all conditions of saturation and loading, and that it provide sufficient resistance to seepage to prevent excessive loss of water. Adverse foundation conditions can lead to failure of a dam due to cracking, piping, sliding, settlement, or uplift.

The foundation conditions under the proposed damsite should be investigated thoroughly to insure that the site is suitable and that a safe structure can be designed. The extent of the foundation examination will depend upon the complexity of the conditions encountered and on the height of the dam. Borings should be taken or test pits excavated at intervals along the centerline of the dam. The depth and spacing of the borings or pits should be sufficient to determine the suitability of the foundation.

AVAILABILITY OF SUITABLE FILL MATERIAL

Fill material must be available in sufficient quantities for construction of the dam and should be located close enough to the site so that placement costs will not be excessive. Soil borings should be made in the selected borrow areas in order to estimate the kinds and amounts of suitable fill materials available.

Materials selected for construction of a dam must have sufficient strength for the dam to remain stable and a sufficiently low permeability, when compacted, to prevent harmful seepage of water through the dam.

SOILS IN THE SPILLWAY AREA

In most cases it is necessary to bypass excess storm runoff around the embankment of a farm pond through an excavated earth spillway. For economic reasons, suitable material excavated from the spillway should be used in the earthfill. Thus, soil borings should be made along the approximate centerline of the proposed spillway to determine the type of material that will be encountered, its erodibility, and its suitability for use in the embankment.

RECORDS OF SOILS INVESTIGATIONS

A permanent record of all soil borings and test pits made in the reservoir area, foundation, borrow area, and spillway area should be maintained in the work unit office. Form SCS 538, Figure 11-4, or a similar form, should be used to record soil borings.

See Chapter 4 of this manual for guidance in the classification of the soils encountered, and in determining their suitability as foundation or construction materials.

2. SPILLWAY REQUIREMENTS

All reservoirs formed by damming natural drainageways require the protection of a carefully designed spillway or a combination of spillways. The function of spillways is to pass storm runoff around or under the embankment to prevent overtopping. The spillway also must convey the water from the pond safely to a stable outlet below without damage to the downstream slope of the embankment. Spillways are usually classified as trickle tubes, principal spillways, and emergency spillways.

3. TRICKLE TUBES

DEFINITION

A small pipe spillway is provided in many farm ponds and reservoirs to protect the vegetative cover in the emergency spillway from prolonged saturation by continuous flow, spring flow, or low flows that may continue for several days during snowmelt or following a storm. This type of spillway is designed to discharge such a small percentage of the peak flow that

Form SCS 538

SOIL INVESTIGATION TO DETERMINE SUITABILITY OF PROPOSED POND SITE

FARMER'S NAME John M. Doe DISTRICT Greenville
DATE March 1, 1962 COUNTY Greenville
S. C. S. PHOTO SHEET NO. AX-16B-422 WORK UNIT Greenville

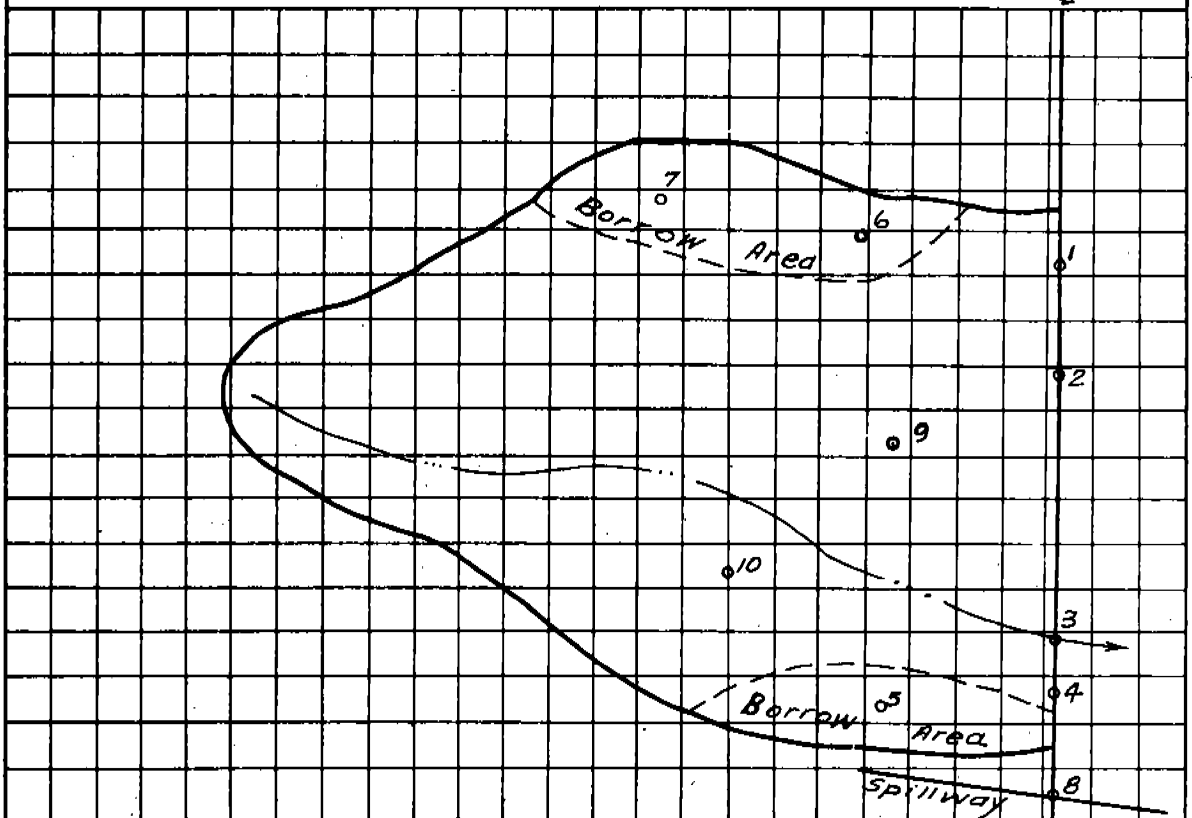
WATERSHED AREA MEASUREMENTS

CROPLAND 10 ACRES PASTURE 14 ACRES
WOODLAND 11 ACRES TOTAL 35 ACRES

POND CLASS

H. Smith
WORK UNIT CONSERVATIONIST

SKETCH OF PROPOSED POND SHOWING WHERE BORINGS WERE MADE (Approx. scale 1″ = ______ feet)
Locate reference point on center line of dam and identify on sketch.



BORING NUMBER AND PROFILE
Make and list dam-site and spillway borings first - then ponded area and borrow pit borings - separate with vertical red line. (Continued on back where necessary) Show water table elevations on dam-site borings.

SHOW DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1.0	SM	SM	ML	SM	SC	SM	SM	SC	ML	ML													
2.0	CL	SM	ML	CL	SC	CL	SM	SC	SM	ML													
3.0	CL	SM	SM	CL	SC	CL	SM	SC	SM	ML													
3.5	CH	CL	SM	CL	SM	CL	CL	SM	SM	SM													
4.0	CH	CL	CL	CH	SM	CL	CL	SM	SM	SM													
5.0	CH	CL	CL	CH	CL	CH	CL	CL	CH	CL													
6.0	CH	CH	CH	CH	CH	CH	CH	CL	CH	CL													

BORINGS MADE BY P. D. Waters SIGNATURE & TITLE P. D. Waters Area Engr.

Figure 11–4 Soil investigation form.

(Sheet 1 of 2)

TYPES OF MATERIAL ENCOUNTERED IN BORINGS

GW Well graded gravels; gravel-sand mixtures
GP Poorly graded gravels
GM Silty gravels; gravel-sand-silt mixtures
GC Clayey gravels; gravel-sand-clay mixtures
SW Well graded sands; sand-gravel mixtures
SP Poorly graded sands
SM Silty sand
SC Clayey sands; sand-clay mixtures
ML Silts; silty, v. fine sands; sandy or clayey silts
CL Clays of low to medium plasticity; silty, sandy or gravelly clays
CH Inorganic clays of high plasticity; fat clays
MH Elastic silts; micaceous or diatomaceous silts
OL Organic silts and organic silty clays of low plasticity
OH Organic clays of medium to high plasticity

1. **Suitable material for embankment is available** ☒ **Yes** ☐ **No** ***(Indicate where located on the sketch on reverse side)***

REMARKS:

Material in borrow areas and spillway area is suitable for embankment fill.

2. **Explain hazards requiring special attention in design** ***(Seepage, spring, rock etc.)***

Clean out old Channel to good material. This should extend for its entire length under the embankment. Backfill with material from borrow area, and compact as required for maximum density.

GENERAL REMARKS:

Site is satisfactory for stock water pond.

24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51

Figure 11–4 Soil investigation form.

Sheet 2 of 2

it has no measurable effect on the emergency spillway design. This type of spillway is commonly called a trickle tube.

DESIGN CAPACITY

The design capacity of a trickle tube should be adequate to discharge long-duration, continuous, or frequent flows without flow through the earth spillway.

4. PRINCIPAL SPILLWAYS

DEFINITION

The principal spillway is constructed of permanent material, and usually is designed to provide flood protection or to reduce the frequency of operation of the emergency spillway. Its discharge capacity depends upon the purpose of the reservoir and the use for which the spillway is designed. If the reservoir is to be used for retarding flood flow, it discharges a low percentage of the peak flow. At locations where an emergency spillway is not feasible the principal spillway should be designed to discharge the runoff for the design storm.

DROP INLET SPILLWAYS

One type of principal spillway that is commonly used with farm ponds and reservoirs is the drop inlet spillway. It consists of a pipe barrel located under the embankment with a riser connected to the upstream end. The elevation of the crest of the riser determines the normal pool level in the reservoir. This type of spillway may be used to drain the pond or to supply water for irrigation or other purposes by installing a valve or gate in the upstream end of the barrel.

Design

Small diameter pipes are particularly susceptible to clogging with trash and rodents. For this reason no barrel smaller than 6 inches in diameter and no riser smaller than 8 inches in diameter should be used. Where the riser is to be constructed of reinforced concrete or concrete block, the inside dimensions should not be smaller than 24 by 24 inches.

The crest elevation of the emergency spillway should be located at an elevation above the crest of the drop inlet equal to the head required to develop design flow through the principal spillway conduit.

Drawings and design information are given in Chapter 6 of this manual. Construction methods and materials are covered in Chapter 17. Also see Exhibit 11-4 for determining the capacity of principal spillways considering temporary storage.

HOOD INLET SPILLWAYS

Another type of principal spillway commonly used with farm ponds and reservoirs is the hood inlet spillway. It consists of a pipe laid in the earth embankment in a manner that the elevation of the invert of the pipe at its upstream end establishes the normal pool level in the reservoir. The inlet end of the pipe is cut at an angle to form the hood. An anti-vortex device, usually made of metal, is attached to the entrance of the pipe to increase the hydraulic efficiency of the tube. The hood inlet spillway often can be constructed at less cost than the drop inlet type because there is no expense for a riser. This type of spillway has one major disadvantage in that it cannot be used as a drain or water supply pipe.

Pipe smaller than 6 inches in diameter should not be used because of the danger of becoming clogged. The crest elevation of the emergency spillway should be located a distance above the invert or crest elevation of the hood inlet spillway at least equal to the value of the minimum head, h, required to provide full pipe flow, but in no case less than 12 inches.

See Chapter 6 of this manual for further design information and typical installations, and Chapter 17 for construction methods and materials. See Exhibit 11-4 for determining the capacity of principal spillways considering temporary storage.

5. EMERGENCY SPILLWAYS

An emergency spillway is an earth or a vegetated channel, usually designed to discharge flow in excess of the principal spillway design discharge. Where watersheds are small and long duration flows are not a problem, it may be feasible to handle the runoff safely with only a vegetated spillway.

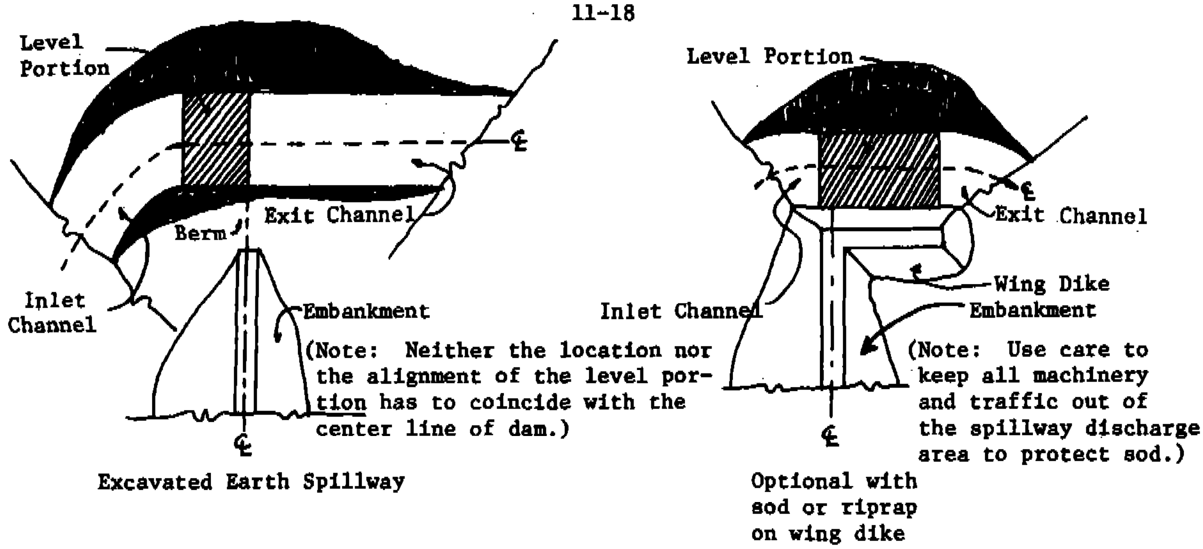
Emergency spillways, as discussed here, apply to both the vegetated and nonvegetated spillways, the latter being used where climatic or soil conditions make it impossible to grow or maintain a suitable grass cover. Emergency spillways are usually excavated, but may exist as a natural spillway such as natural draw, saddle or drainageway. In either case the spillway must discharge the design peak flow at a non-erosive velocity to a safe point of release. Ordinarily, emergency spillways, whether vegetated or nonvegetated, should not be built on fill material.

LIMITATIONS

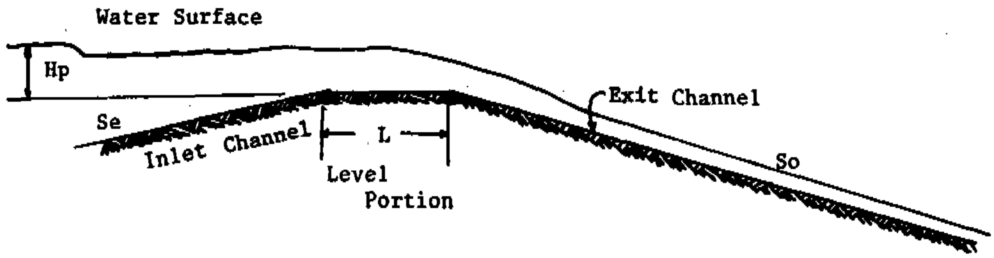
Emergency spillways have certain limitations. They should be used only where the soils and topography will permit safe discharge of the peak flow at a point well away from the dam and at a velocity which will not cause appreciable erosion. Temporary flood storage provided in the reservoir may be used to reduce the design flow or frequency of use of the spillway.

DESIGN SPILLWAY CAPACITY

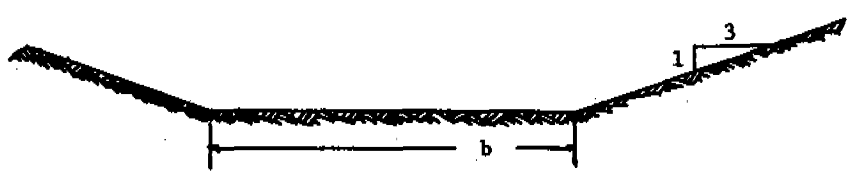
Emergency spillways should have the minimum capacity to discharge the peak flow expected from a design storm of the frequency and duration shown in the following table less any reduction creditable to conduit discharge and detention storage. The procedure for determining peak flood flow is presented in Chapter 2 of this manual.



PLAN VIEW OF EARTH SPILLWAYS



PROFILE ALONG CENTERLINE



CROSS-SECTION OF LEVEL PORTION

Definition of terms:

Hp = Depth of water in reservoir above crest
L = Length of level portion min 7.6 meter (25 ft.)
b = Bottom width of spillway
So = Slope for exit channel
Se = Slope of inlet channel

Figure 11-5: Profile and cross-section of excavated earth spillway

Minimum Spillway Capacity (SI Units)

Drainage area	Effective height of dam	Storage	Minimum design storm Frequency	Minimum duration
hectare	m	*dam^3	yr.	hr.
8 or less	6 or less	less than 60	10	24
8 or less	more than 6	less than 60	25	24
More than 8	6 or less	less than 60	25	24
all other			50	24

*dam (cubic dekameter) = 1,000 m^3

Minimum Spillway Capacity (English Units)

Drainage area	Effective height of dam	Storage	Minimum design storm Frequency	Minimum duration
acre	ft	acre-ft	yr.	hr.
20 or less	20 or less	less than 50	10	24
20 or less	More than 20	less than 50	25	24
More than 20	20 or less	less than 50	25	24
all other			50	24

EXCAVATED SPILLWAYS

Elements of Excavated Spillways

Excavated spillways consist of the three elements shown in Figure 11-5. These are inlet channel, level portion, and exit channel. Each element has a special function. The flow enters the spillway through the inlet channel. The depth of flow Hp located upstream from the level portion is controlled by the inlet channel, level portion, and exit channel. The flow is controlled in the level portion and then discharged through the exit channel. Flow in the exit channel can be either subcritical, critical, or super critical.

Excavation of the inlet channel or the exit channel, or both, may be omitted where the natural slopes meet the minimum slope requirements. The direction of slope of the exit channel must be such that discharge will not flow against any part of the dam. Wing dikes, sometimes called kicker levees or training levees, may be used to direct the outflow to a safe point of release.

The spillway should be excavated into original earth for the full design depth. Where this is not practical, the end of the dam and any earthfill constructed to confine the flow should be protected by vegetation or riprap. It is desirable that the entrance to the inlet channel be widened so it is at least 50 percent greater than the design bottom width of the level portion. The inlet channel should be reasonably short and should be planned with smooth, easy curves for alignment. It should have a slope toward the reservoir of not less than 2.0 percent, except in rock, to insure drainage and low inlet losses.

The level portion should be located near the intersection of the extended centerline of the dam with the centerline of the spillway and have a length of at least 7.5 meters (25 feet).

The exit channel must have a slope that is adequate to discharge the peak flow within the channel. The slope, however, must be no greater than that which will result in maximum permissible velocities for the soil type or the planned grass cover. The exit channel should be straight and should confine the outflow to a point where the water may be released without damages to the fill.

Selecting Spillway Dimensions

With the required discharge capacity, the degree of retardance, permissible velocity, and the natural slope of the exit channel known, the bottom width of the level and exit sections and the depth of the flow (Hp) may be computed from Exhibit 11-2. The natural slope of the channel should be altered as little as possible.

The selection of the degree of retardance for a given spillway will depend mostly upon the height and density of the cover chosen (Exhibit 11-2, Table 2). Generally, after the cover is selected, the retardance with a good uncut condition will be the one to use for capacity determination. Since a condition offering less protection and less retardance exists during the establishment peroid and after mowing, it may be advisable to use a lower degree of retardance when designing for stability.

When the anticipated average use of a spillway is more frequent than once in 5 years, the maximum permissable velocities shall be in accordance with Exhibit 11-2, Table 1 for vegetated spillways and Exhibit 11-2, Table 4 for earth spillways. For vegetated spillways only, the maximum permissible velocity may be increased 10 percent when the anticipated average use is not more frequent than once in 5 years or 25 percent when the anticipated average use is not more frequent than once in 10 years.

Water surface profiles were calculated by computer for all the anticipated spillway conditions and based on the retardances described in SCS TP-61. Critical slope and depth proved to be of minor importance in setting Hp, so Exhibit 11-2, Tables 3A through E were developed from the water surface profiles and will carry the design flow as shown. Tables 3A through E give minimum and maximum slope requirements for the various discharges q, velocities V, and retardance given.

Some velocities in Exhibit 11-2 Tables 3A - E show different discharges in $m^3/s/m$ ($ft^3/s/ft$) for the same Hp values. The Hp values are set to insure design q at the minimum slope, but velocities at minimum slope may not reach maximum velocity. The maximum velocity will only be achieved where the exit channel is at maximum slope. Rounding is also part of the reason. Table 3A - E are not appropriate for bottom widths less than 2.4 meters (8 feet). Table 3E should be used for earth spillways.

Spillway side slopes should be no steeper than 3:1 unless the spillway is excavated into rock, in which case the side slopes may be vertical.

Usually the selected bottom width of the channel should not exceed 35 times the design depth of flow. Where this ratio of bottom width to depth is exceeded, the channel is likely to be damaged by meandering flow and accumulated debris. Whenever the required bottom width of the spillway is excessive, consideration should be given to the use of a spillway at each end of the dam. These two spillways need not be of equal width so long as their total capacity meets requirements. In cases where the required discharge capacity exceeds the ranges shown in the above exhibits, or topographic conditons will not permit the construction of the exit channel bottom with a slope that falls within the ranges shown in these exhibits, the design is beyond the scope of this manual.

See Exhibit 11-4 for principal spillway discharge requirements adjusted for temporary storage provided in the reservoir. Emergency spillway design flow may be adjusted to consider the outflow through the principal spillway.

NATURAL SPILLWAYS

Many times large expanses of good sod are destroyed to provide the minimum slopes for an excavated spillway. This may increase the construction cost and will increase maintenance costs. Wherever there is a good vegetative cover in the spillway area and the topography suitable, consideration should be given to the use of a natural spillway. The discharge capacity can be computed by the following procedures.

Discharge Through Natural Vegetated Spillways

In a natural spillway the outflow takes place around the end of the embankment on natural or undisturbed ground. The number of possible cross sections and profile shapes is so great that an analysis here of the rate of flow for each condition is impractical.

In most cases the level portion of the flow route will be V-shaped, one side determined by the embankment end slope and wing dike, and the other by the natural ground. The ground slope should be determined along a line perpendicular to the contour direction within the flow depth range. See Figure 11-6.

The end of the dam should be approximately perpendicular to the contours of the abutment. A short wing dike may be used to protect the toe of the embankment. The exit slope away from the control section should be within the slope ranges given in Exhibit 11-5.

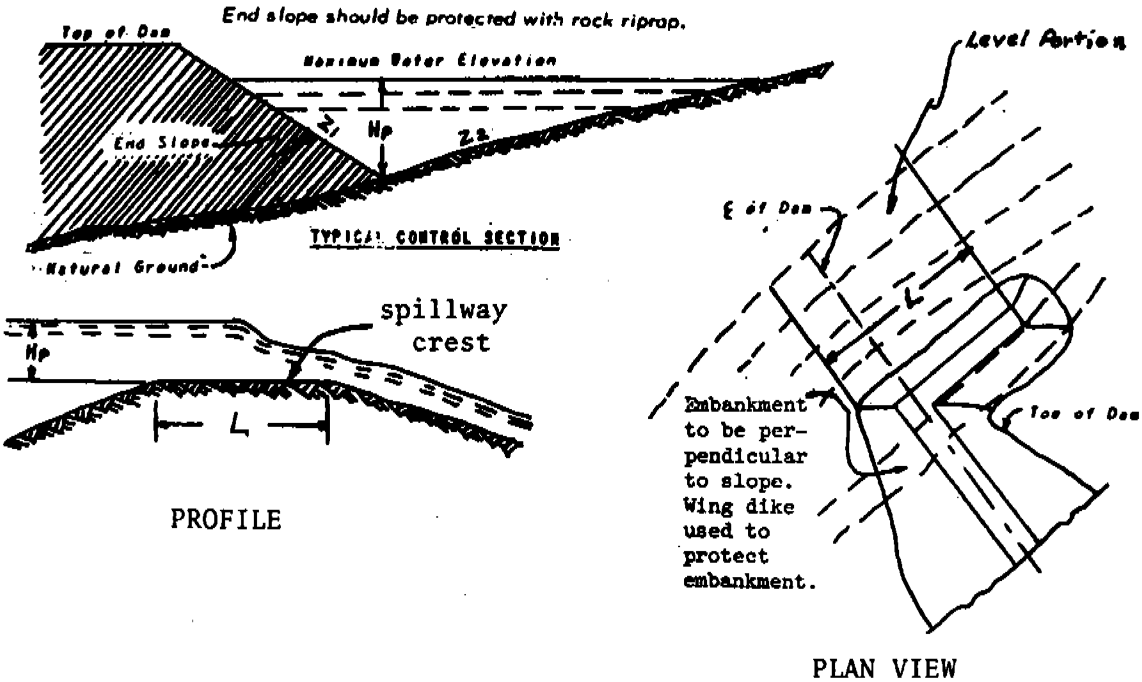


Figure 11-16 Plan, profile and cross section of a natural vegetated spillway.

Discharge (Q), velocity (V) and depth of water in the reservoir above the crest (Hp), were determined using water surface profiles calculated by computer. The spillway was segemented into 0.6 meter (2 foot) segments, then using data from water surface profiles a discharge for each segement was determined for a specific depth, length of flow, and retardance. Total Q is the sum of the discharges of each segement. Exhibit 11-5 was then developed using the given parameters.

Determining the Maximum Water Elevation in Reservoir

With the required discharge capacity (Q), the end slope of the embankment (Z_1), and the slope of the natural ground (Z_2), known; the maximum depth of water above the level portion (Hp), can be obtained from Exhibit 11-5. The depth is added to the elevation of the spillway crest to determine the maximum elevation to which water will rise in the reservoir.

Exhibit 11-5 has been developed for an end slope of 3:1 and natural ground slopes of 1 to 5 percent.

An example showing the use of Exhibit 11-5 is as follows:

(SI Units)

Given:

Q = $2.43\ m^3/s$ (From Chapter 2)

Vegetation: Bermudagrass Good Stand

Height: 15 to 25 cm

Slope of Natural Ground 1.0%

Solution:

From Table 2 Exhibit 11-2:

Determine a Retardance of C

From Exhibit 11-5:

Enter under Z_2 slope 1%

Under Retardance C column

find a Q = $2.43\ m^3/s$

at Hp = 0.40 m and

V = 0.82 m/s

(English Units)

Given:

Q = $86\ ft^3/s$ (From Chapter 2)

Vegetation: Bermudagrass Good Stand

Height: 6 to 10 inches

Slope of Natural Ground 1.0%

Solution:

From Table 2 Exhibit 11-2:

Determine a Retardance of C

From Exhibit 11-5:

Enter under Z_2 slope 1%

Under Retardance C column

find a Q = $86\ ft^3/s$

at Hp = 1.3 ft and

V = 2.7 ft/s

Velocity is well below the maximum permissable velocity of 2.4 m/s (8 ft/s) given in Table 1 Exhibit 11-2. Hp can be determined by interpolation when necessary. For a Q greater than listed in Exhibit 11-5, the spillway should be excavated according to Exhibit 11-2.

PROTECTION AGAINST EROSION

Earth spillways should be protected against erosion by a good vegetal cover, if soil and climate permit. As soon after construction as is practical, the entire spillway area should be thoroughly prepared for seeding or sodding. Liberal amounts of fertilizer should be used where moisture is available or can be applied. In cases where the subsoil is low in fertility, it may be desirable to save the topsoil and spread it in the excavated spillway. Adapted perennial grasses or perennial grasses and legumes should be sown, protected, and treated until a good stand has been established. Mulching is usually necessary to protect the seeding on the spillway slopes. Irrigation of the spillway area is often needed to assure adequate germination and growth, particularly when seeding must be done during relatively dry periods. Where the added cost is justified, sprigging or sodding with suitable grasses will afford quick protection.

6. DRAINS AND WATER SUPPLY PIPES

DRAIN PIPES

Some state agencies require that provision be made for draining farm ponds, fluctuating the water surface elevation to eliminate breeding places for mosquitos, or meeting other State requirements. Providing for drainage of farm ponds is a desirable practice in that it permits good fish management and allows for maintenance and needed repairs without cutting the fill or resorting to other devices to remove the water. The drain pipe should be extended beyond the upstream toe of the dam and be equipped with a suitable gate or valve.

WATER SUPPLY PIPES

A water supply pipe should be installed under or through the dam where water is to be used below the dam, such as for stockwater, irrigation, or filling a spray tank. This pipe usually is in addition to the principal spillway or trickle tube. The water supply pipe should have water-tight joints and be equipped with a suitable valve and strainer at its upper end. For small rates of flow, such as are needed to fill livestock or spray tanks, 1½-inch diameter steel pipe is generally used. Where larger rates of flow are required, such as for irrigation purposes, larger diameter pipe are commonly used. Water supply pipes should be provided with anti-seep collars to retard seepage. (See Figure 11-7 for a sketch of a stock watering facility.)

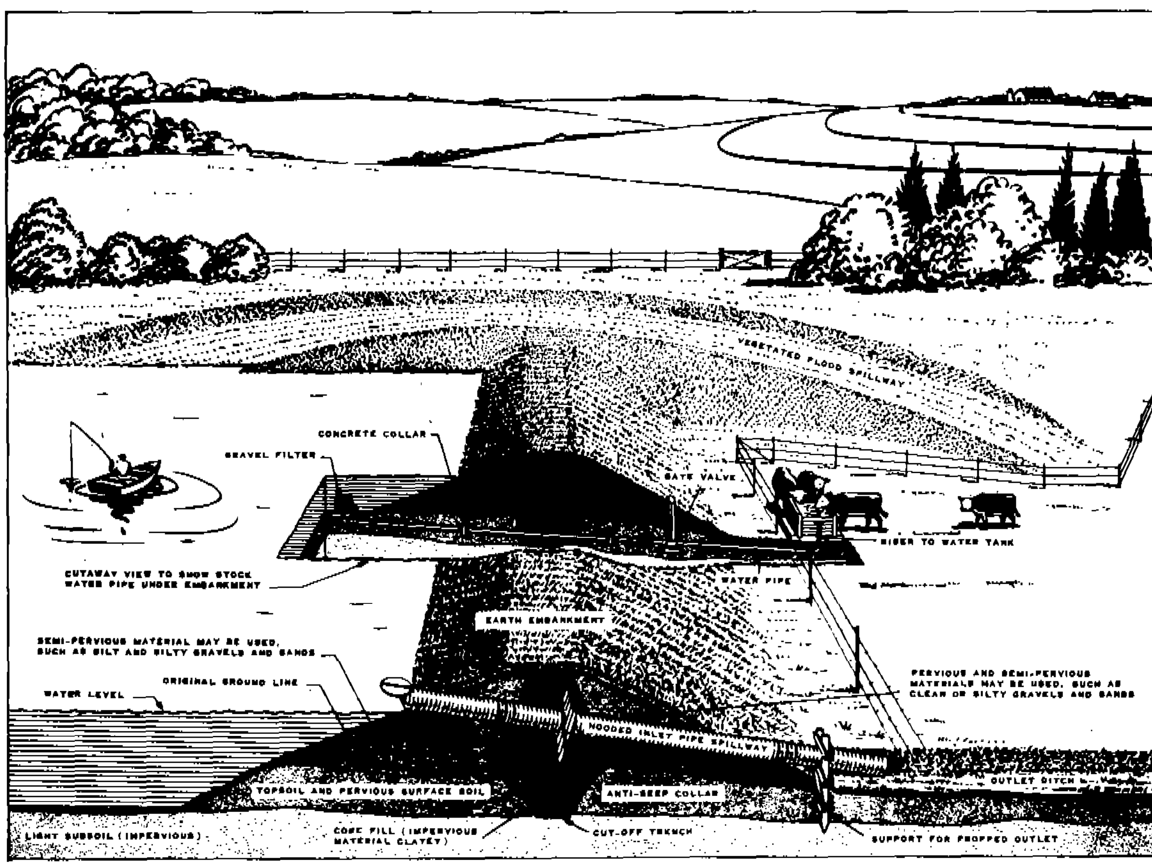


Figure 11-7 Embankment pond equipped with a stock watering facility

7. DESIGN OF EARTHFILL EMBANKMENTS

FOUNDATIONS

It is possible to construct a safe earthfill dam on almost any foundation if the foundation has been thoroughly investigated and the design and construction procedures are adapted to site conditions. Some foundation conditions require construction measures that are relatively expensive which, in the case of small farm ponds, cannot be justified. Sites with such foundation conditions ordinarily should be abandoned.

The most satisfactory foundation is one that consists of, or is underlain at a shallow depth by a thick layer of relatively impervious consolidated material. Such foundations cause no stability problems. Where a suitable layer occurs at the surface, no special measures are required. It is sufficient to remove the top-soil and scarify or disk the area to provide a bond with the material in the dam.

Where the impervious layer is overlain by previous material a compacted clay cutoff, extending from the surface of the ground into the impervious layer, is required to prevent possible failure by piping and to prevent excessive seepage.

Where the foundation consists of highly pervious sand or sand-gravel mixture and any impervious clay layer is beyond economical reach with available equipment, a detailed investigation should be made. While such a foundation might be satisfactory insofar as stability is concerned, corrective measures will be required to prevent excessive seepage and possible failure.

A foundation consisting of or underlain by a highly plastic clay or unconsolidated material requires a very careful investigation and design in order to obtain stability.

Water impounded on bedrock foundations seldom gives cause for concern unless the rock contains seams, fissures or crevices through which water may escape at an excessive rate. Where rock is encountered in the foundation, a very careful investigation of the nature of the rock is required.

See Chapters 4 and 17 of this manual for further guidance.

FOUNDATION CUTOFFS

Where the foundation consists of pervious materials at or near the surface, with rock or impervious materials at a greater depth, seepage through the pervious layer should be reduced to prevent piping and excessive losses. Usually a cutoff joining the impervious stratum in the foundation with the base of the dam is needed.

The most common type of cutoff is one constructed of compacted clayey material. A trench is cut parallel to the centerline of the dam to a depth that extends well into the impervious layer. The trench is extended into and carried up the abutments of the dam as far as pervious material exists that might allow seepage under the embankment. The trench should have a bottom width of not less than 4 feet but adequate to allow use of equipment necessary to obtain proper compaction. Its sides should be no steeper than 1:1. The trench should be filled with successive thin layers of relatively impervious material, each layer being thoroughly compacted at near optimum moisture conditions before the succeeding layer is placed. Any water collected in the trench should be removed before backfill operations are started. (See Chapter 17 of this manual).

EMBANKMENT TOP WIDTH

A conservative top width for dams under 10 feet in height is 8 feet. The top width should be increased as the height of the dam increases. Table 11-4 contains recommended top widths for embankments of various heights. See State Standards and Specifications for local requirements.

Where the top of the embankment is to be used for a roadway, the top width should provide for a shoulder on each side of the traveled way to prevent raveling. The top width in such cases should not be less than 14 feet.

Table 11-4. Recommended top widths for earth embankments

Height of Dam (feet)	Top Width (feet)
Under 10	8
10 to 15	10
15 to 20	12
20 to 25	14

EMBANKMENT SIDE SLOPES

The side slopes of a dam depend primarily on the stability of the material in the embankment. The greater the stability of the fill material, the steeper the side slopes may be. The more unstable materials require flatter side slopes. Table 11-5 contains recommended maximum slopes for the upstream and downstream faces of dams constructed of various materials. See State Standards and Specifications for local requirements.

Table 11-5. Recommended side slopes for earth embankments

Fill Material		Side Slopes Horizontal to Vertical	
		Upstream	Downstream
	Clay CH		
Clayey sand SC	Sandy clay CL	3 to 1	2 to 1
Silty clay CL	Silty sand SM	or	or
Clayey gravel GC	Silty gravel GM	2½ to 1	2½ to 1
Silt ML or MH	Clayey silt ML	3 to 1	3 to 1

FREEBOARD

Freeboard is the added height of the dam provided as a safety factor to prevent waves or runoff from storms greater than the design frequency from overtopping the embankment. It is the vertical distance between the elevation of the water surface in the pond when the spillway is discharging at designed depth and the elevation of the top of the dam after all settlement has taken place. Where the maximum length of a pond is less than 660 feet, a freeboard of not less than 1.0 foot should be provided. For ponds with lengths between 660 and 1,320 feet the minimum freeboard should be 1.5 feet. For ponds up to ½ mile in length, the minimum freeboard should be 2.0 feet. See State Standards and Specifications for local requirements.

ALLOWANCE FOR SETTLEMENT

Settlement includes the consolidation of the fill materials and the consolidation of the foundation materials due to the weight of the dam and the increased moisture caused by the storage of water.

Settlement or consolidation depends on the character of the materials in the dam and foundation and on the methods and speed of construction. The design height of earth dams should be increased by an amount equal to the estimated settlement. This increase should not be less than 5 percent.

EARTHWORK COMPUTATION

The estimate of the volume of borrow required should include the dam, allowance for settlement, backfill for the cutoff trench, backfill for existing stream channels and holes in the foundation area, and any other embankment the contractor is required to perform.

Volume estimates for dams usually are made on the basis of cubic yards of earthfill in place. The common method of estimating the volume of earthfills is the "sum of end areas" method. With the fill heights, side slopes and top width established, the end area of the cross section at each station along the centerline may be obtained from Exhibit 11-6.

For example, assume that a dam has slopes of 3 to 1 on both upstream and downstream sides and a top width of 12 feet. For a point along the centerline where the fill height is 15.0 feet, the exhibit shows that the end area at that point is 675 + 180 or 855 square feet. The number of cubic yards of fill between two points on the centerline of the dam is equal to the sum of the end areas at the two points multiplied by the distance between these points and divided by (2 x 27) or 54. The total volume of earthfill in the dam is the sum of all such segments. A sample volume estimate illustrating the use of the "sum of end areas" method is presented in Table 11-6.

Table 11-6. Sample volume computations using "sum of end areas" method

Station	Ground Elevation	Fill Height (feet)	End Area 1/ (sq.ft.)	Sum of End Areas (sq.ft.)	Distance (feet)	Double Volume (cu.ft.)
0 + 50	35.0	0.0	0			
				44	18	792
+ 68	32.7	2.3	44			
				401	32	12,832
1 + 00	25.9	9.1	357			
				1066	37	39,442
+ 37	21.5	13.5	709			
				1564	16	25,024
+ 53	20.0	15.0	855			
				1730	22	38,060
+ 75	19.8	15.2	875			
				1781	25	44,525
2 + 00	19.5	15.5	906			
				1730	19	32,870
+ 19	20.3	14.7	824			
				1648	13	21,424
+ 32	20.3	14.7	824			
				1805	4	7,220
+ 36	18.8	16.2	981			
				2030	4	8,120
+ 40	18.2	16.8	1049			
				2064	3	6,192
+ 43	18.5	16.5	1015			
				1911	3	5,733
+ 46	19.6	15.4	896			
				1771	13	23,023
+ 59	19.8	15.2	875			
				1650	41	67,650
3 + 00	20.8	14.2	775			
				1023	35	35,805
+ 35	27.7	7.3	248			
				324	25	8,100
+ 60	31.6	3.4	76			
				76	36	2,736
3 + 96	35.0	0.0	0			
					Total 2/	379,548

1/ End areas based on 12-foot top width and 3 to 1 slopes on both sides.
2/ Double volume in cu.ft. is divided by 54 to obtain volume in cu.yds.

$\frac{379,548}{54}$ = 7,029 cu. yds.

Allowance for settlement (5%) = 351 cu. yds.

Total Volume = 7,380 cu. yds.

The sample volume estimate of 7,380 cubic yards includes only that volume of earth required to complete the dam itself. An estimate of the volume of earth required to backfill the core trench, old stream channels and other required excavation should be made and added to the estimate made for the dam. For example, assume that in addition to the volume shown in Table 11-6, there is a cutoff trench to be backfilled. The dimensions of the trench are as follows:

Average depth	=	4.0 feet
Bottom width	=	8.0 feet
Side slopes	=	1 to 1
Length	=	177 feet

The volume of backfill is computed as follows:

$$\text{End Area} = (8 \times 4) + (4 \times 4) = 32 + 16 = 48 \text{ square feet.}$$

$$\text{Volume} = \frac{48 \times 177}{27} = 315 \text{ cubic yards.}$$

Adding this to the volume required for the dam itself, the total volume becomes 7,380 + 315 = 7,695 cubic yards.

PLANS AND SPECIFICATIONS

All information developed during the design process should be recorded in the form of an engineering plan for the pond. This plan should show all pertinent elevations and dimensions of the dam, the dimensions and extent of the cutoff trench and other areas requiring backfill, the location and dimensions of the trickle tube and other planned appurtenances, and all other information pertinent to the construction of the dam. The plan should also include a bill of materials listing the quantity and type of all construction materials required. A sample plan of a farm pond embankment is shown in Figures 11-8 and 11-9.

Applicable engineering standards and construction specifications have been developed in each state for ponds and reservoirs. To obtain a quality job of construction the owner and contractor must understand all requirements. Both the owner and the contractor should be furnished copies of the plans and specifications.

8. STAKING FOR CONSTRUCTION

Staking is a means whereby the information on the farm pond plans is transmitted to the job site. This information will provide lines, grades, and elevations required for construction of the job in accordance with the plans. Consideration should be given to the contractor's wishes in staking so that he can make the most effective use of the stakes. The quality and appearance of the completed job will reflect the care and thoroughness exercised in the staking procedure.

DESIGN DATA	
Drainage Area	90 Acres
Avg. Slope	Moderate
Land Use	Pasture
Treatment	Good Condition
Hydr. Soil Group	D
Curve No.	80
Design Freq.	25-Yr., 24-Hr.
Storm Distr.	Type I
Storm Rainfall	8.5
Runoff Depth	6"
Peak Runoff	160 cfs

4-28467 Rev. 12-68

GENERAL INFORMATION

Uses for Impounded Water: Livestock & Fish

Area at Normal Pool = 7.5 Acres Maximum Depth = 12.0 feet

Capacity = 0.40 x 7.5 ac. x 12 feet = 36 acre feet

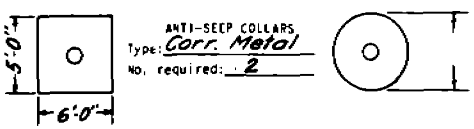
Source of Water: Surface Runoff

EARTH QUANTITIES

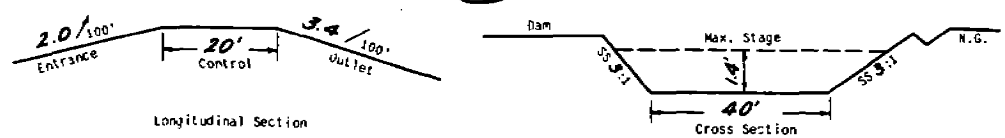
Embankment	7,380	cu. yds.
Excavation of Cutoff Trench	315	cu. yds.
Excavation of Stream Channel	None Required	cu. yds.
Other Excavation ( )	" "	cu. yds.
Total	7,695	cu. yds.

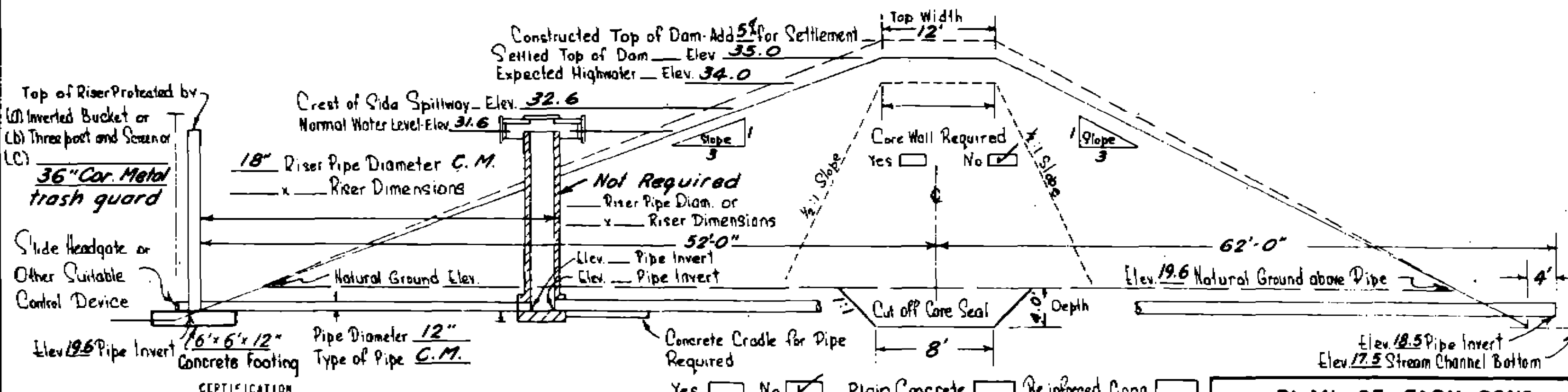
BILL OF MATERIALS

12 lin. ft. 18" C.M. pipe (riser)
114 lin. ft. 12" C.M. pipe (barrel)
1 each 12" x 18" C.M. cross
2 each 5' x 6' C.M. diaphrams
1 each 36" C.M. trash guard
1 each 18" slide headgate w/frame
1.33 cu. yds. concrete for footing under riser pipe 6'x6'x12"



Emergency Spillway Located (Right) (Left) Side of Dam Looking Downstream





SECTION THROUGH FILL ALONG CONDUIT

Bench Mark Description: Nail in root 30" Oak 140' NW of N. end of dam.

Mark out with red pencil those items not required.

CERTIFICATION

I certify that I have made, or caused to be made, a final inspection of this pond project and that all work related thereto has been completed in accordance with these plans and with all other applicable specifications except as listed on the attached sheet.
(Check here ✓ if no exceptions)

Signed J. Scruggs Title Cons. Aide Date 10-1-63

PLAN OF FARM POND

W. J. Sprinkle Farm

Cherokee County

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date		
Designed	S. Wolfe	6/63	Approved by	C. Allen
Drawn	J. Scruggs	6/63	Title	Area Eng.

Figure 11–8 Sample plan of farm pond

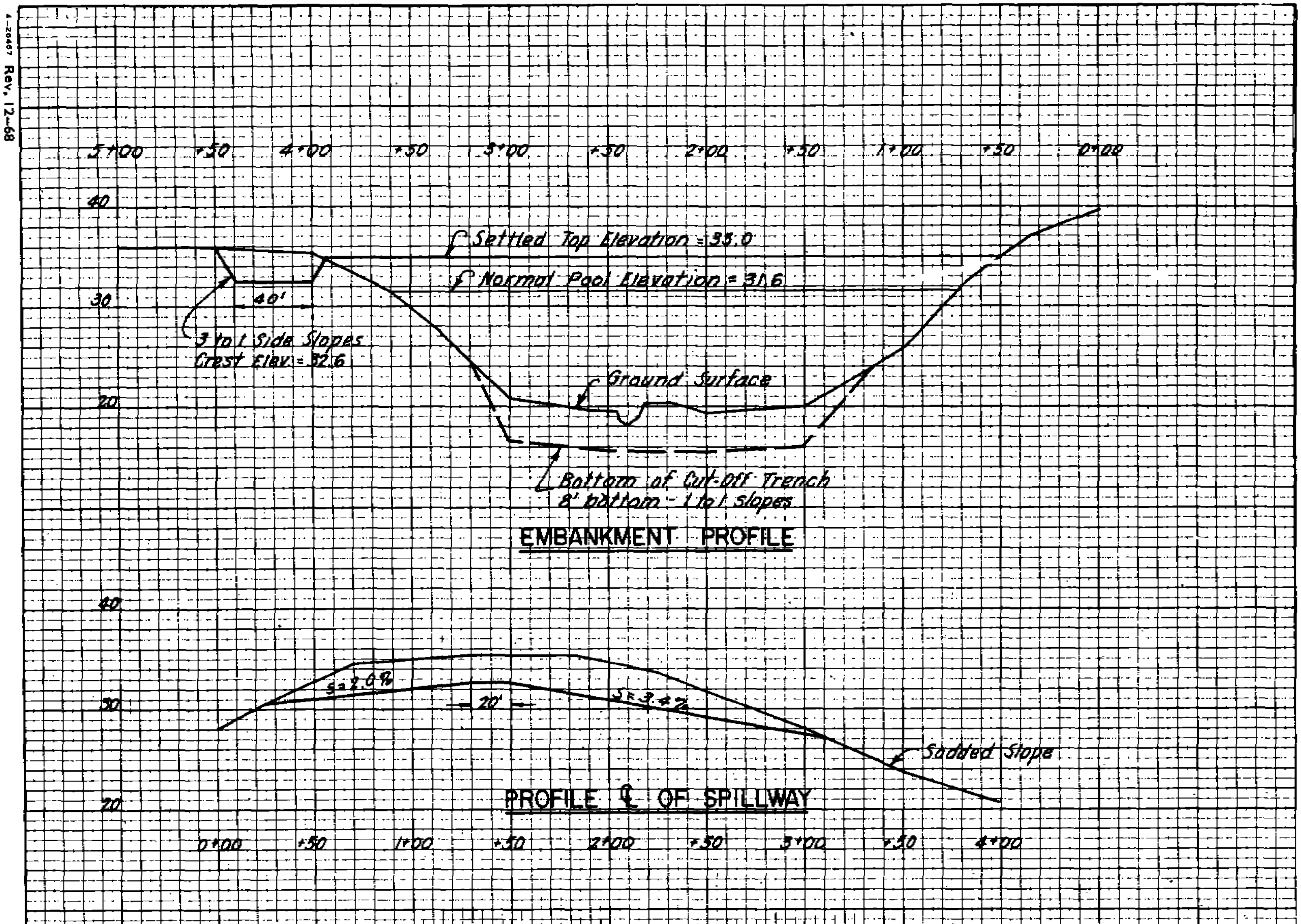


Figure 11–9 Sample profiles of embankment and spillway

The areas to be cleared usually will consist of the damsite, the spillway site, the borrow area, and the area over which water is to be impounded. Each of these areas should be clearly marked with stakes or flags. In the case of the pond area, the proposed waterline should be located accurately with a level and rod. Clearing stakes should be at least 15 feet outside this waterline to give a cleared area around the edge of the reservoir.

The embankment is located by setting stakes along its centerline at intervals of 50 feet or less. Usually this will have been done during the course of the initial planning survey. Fill and slope stakes are then set both upstream and downstream from the centerline stakes marking the points of intersection of the side slopes with the ground surface. See Chapters 1 and 17 for procedures on slope staking.

The earth spillway is located by staking the centerline and then setting cut and slope stakes along the lines of intersection of the spillway side slopes with the natural ground surface. The procedure for setting these stakes is the same as for staking the embankment, except that they are cut stakes rather than fill stakes. They should be offset so they will remain in place for ready reference during construction.

Where suitable fill material must be obtained from a borrow area, it is essential that this area be clearly located. Cut stakes should be set to control excavation within the limits of suitable material and to drain the borrow area.

A principal spillway or trickle tube should be located by stakes offset from the centerline of the conduit and placed at intervals not exceeding 50 feet. The principal spillway should be located where it will rest on a firm foundation. Cuts from the tops of the stakes to the grade elevation of the tube should be plainly marked on the stakes. The locations of the riser, drainage gate, antiseep collars, conduit, outlet structure, and other appurtenances should be located by additional stakes, clearly marked.

Figure 11-10 presents a sample set of construction layout notes for an embankment and earth spillway. Design, layout, and check notes may be recorded on approved standard forms or data sheets.

9. CONSTRUCTION METHODS AND SPECIFICATIONS

Attention to details of construction and adherence to specifications are as important as adequate investigations and safe design. A safe design can be ruined by poor construction.

Chapter 17 of this manual provides guidance on construction methods for the various elements of a pond or reservoir. Specifications for the work should conform to State Standards and Specifications applicable to the site and the purpose of the structure.

W.J. Sprinkle - Pond Const. Layout | J. Scruggs ⊼ R. Bishop ϕ | 1

Embankment 6-20-63

Left Slope 3:1 Right Slope 3:1

Top Width = 12'

Nail in root 30" oak 140' N.W. of N. end of dam.

Sta.	B.S.	H.I.	F.S./G.R.	Elev.	Planned Top Elev.		℄	
		Embankment						
BM 1	1.64	41.64		40.00				
0+50			+6.6		35.0	6.6 F=0.0-6.0	6.6 F=0.0	6.6 F=0.0-6.0
+68			+6.6		35.0	8.8 F=2.2-12.6	8.9 F=2.3	9.0 F=2.4-13.2
T.P.1	1.12	30.11	12.65	28.99	+0.1			
1+00			-4.9		35.0 +0.5	3.9 F=8.8-32.4	4.2 F=9.1	4.7 F=9.8-34.8
+37			-4.9		35.0 +0.7	8.0 F=12.9-44.7	8.6 F=13.5	9.0 F=13.9-47.7
+53			-4.9		35.0 +0.7	9.6 F=14.5-49.5	10.1 F=15.0	10.8 F=15.7-53.1
2+00			-4.9		35.0 +0.8	9.9 F=14.8-50.4	10.6 F=15.5	11.1 F=16.0-54.0
+32			-4.9		35.0 +0.7	9.3 F=14.2-48.6	9.8 F=14.7	10.5 F=15.4-52.2
+59			-4.9		35.0 +0.8	9.6 F=14.5-49.5	10.3 F=15.2	10.8 F=15.7-53.1
3+00			-4.9		35.0 +0.7	8.8 F=13.7-47.1	9.3 F=14.2	10.0 F=14.9-50.7
+35			-4.9		35.0 +0.4	2.4 F=7.3-27.9	2.4 F=7.3	2.7 F=7.6-28.8

W.J. Sprinkle - Pond Const. Layout | 2

Sta.	B.S.	H.I.	F.S./G.R.	Elev.	Planned Top Elev.		℄	
		30.11						
TP 2	12.62	41.42	1.31	28.80				
3+60			+6.4		35.0 +0.2	9.8 F=3.4-16.2	9.8 F=3.4	9.9 F=3.5-16.5
+96			+6.4		35.0	6.4 F=0.0-6.0	6.4 F=0.0	6.4 F=0.0-6.0
		Earth Spillway			Bottom Elev.	Bottom width = 40'	Side Slopes 3:1	
0+27			+10.9		30.5		10.7 C=0.2	10.4 C=0.5-21.5
+48			+10.4		31.0	9.2 C=1.2-23.6	8.8 C=1.6	8.4 C=2.0-26.0
	Approach Section							
+70	Slope = 2.0%		+10.0		31.4	8.2 C=1.8-25.4	7.0 C=3.0	6.6 C=3.4-30.2
1+30			+8.8		32.6	6.7 C=2.1-26.3	5.9 C=2.9	5.6 C=3.2-29.6
+50	℄ Dam Control	Sec.	+8.8		32.6	6.7 C=2.1-26.3	5.9 C=2.9	5.6 C=3.2-29.6
+85			+10.0		31.4	6.5 C=3.5-30.5	6.1 C=3.9	5.7 C=4.3-32.9
	Exit Section							
2+25	Slope = 3.4%		+11.4		30.0	8.1 C=3.3-29.9	7.7 C=3.7	7.3 C=4.1-32.3
+50					29.2	9.1 C=2.3-26.9	8.7 C=2.7	8.3 C=3.1-29.3

Figure 11–10 Construction layout notes.

(Sheet 1 of 2)

Sta.	B.S.	H.I.	F.S./G.R.	Elev.	Bottom Elev.
		41.42			
3+00			+13.9		27.5
BM 1			1.41	40.01	
				(40.00)	+.01

W. J. Sprinkle - Pond
Const. Layout

3

13.9
C=0.0 -20.0

13.4
C=0.5

13.0
C=0.9 - 22.7

Figure 11–10 Construction layout notes (Sheet 2 of 2)

10. POND AND RESERVOIR PROTECTION

A farm pond should not be considered complete until proper protection from erosion, wave action, livestock and other sources of damage has been provided. Ponds that lack such protection may be short-lived, and the cost of maintenance is usually high.

PROTECTION AGAINST EROSION

In most areas the exposed surfaces of the dam, spillway, borrow areas and other disturbed surfaces can be protected against erosion by establishing a good cover of sod-forming grass in accordance with the local Technical Guide.

PROTECTION FROM WAVE ACTION

Occasionally there is need for better protection against wave action than will be provided by a grass cover. Some methods used to provide this protection are earth berms, log booms, and rock riprap.

Berms

A berm, 8 to 10 feet in width, located at normal pond level often will provide adequate protection from wave action. The face of the dam above the berm should be protected by vegetation.

Booms

A boom may consist of a single or double line of logs chained together and securely anchored to each end of the dam. The logs should be tied end to end as close together as is practical. There should be enough slack in the line to allow the boom to adjust itself to fluctuating levels in the reservoir. Double rows of logs should be framed together to act as a unit. The boom should be placed so as to float about 6 feet upstream from the face of the dam for best results. In the case of a curved dam, anchor posts may be required on the face of the dam as well as at the ends in order to prevent the boom from riding on the slope. Booms afford a high degree of protection and are relatively inexpensive, especially in areas where timber is readily available. They should prove satisfactory for the smaller, less important structures.

Riprap

Where the water level in the pond can be expected to fluctuate widely or where a high degree of protection is required, the use of rock riprap is a most effective method of control. Riprap should extend from the top of the dam down the upstream face to a level at least 3 feet below the lowest expected level of the water in the reservoir. Riprap may be placed by machine or by hand. Machine placing requires more stone but less labor in placing. The layer of stone should be at least 12 inches thick. Stones should be durable and large enough not to be displaced by waves.

Where riprap is not continuous to the upstream toe, a berm should be provided on the upstream face to support the layer of riprap. See Chapter 17 for guidance on installing riprap.

Other Methods

Other methods include increasing the top width of the dam, flattening the front slope of the embankment, and applying a layer of coarse sand and gravel on a 10:1 slope. These methods are applicable to arid areas where vegetation is not dependable and rock and timber is not readily available.

FENCING

The complete fencing of embankment-type ponds is recommended where livestock are grazed or fed in adjacent areas. The fencing provides the protection needed to develop and maintain vegetative cover. When combined with a watering facility below the dam, fencing provides good drinking water and eliminates the danger of pollution by livestock. Fencing also improves wildlife environment.

11. CHECKING FOR COMPLIANCE WITH STANDARDS

While both the owner and the contractor have responsibilities for compliance with standards, inspection is also required if high standards are to be maintained.

INSPECTION DURING CONSTRUCTION

There are numerous items in the construction of a farm pond that must be checked during construction. Since it will be impossible for work unit personnel to spend as much time as may be desirable on the job, responsibility must be assumed by the owner. The owner or his representative should be encouraged to watch the construction and report his observations to the work unit staff. If corrective action is necessary, the owner can be advised of the course to follow. The following are items that might be checked by the owner.

1. All clearing and grubbing operations should be completed according to specifications before any work on the embankment is started.

2. Before embankment construction begins the foundation should be properly prepared. The completed cutoff trench should be inspected to insure that it is excavated to impervious material and is free of water before it is backfilled.

3. The completed installation of the drop inlet spillway, drainpipe antiseep collars and other appurtenance should be inspected before embankment construction is started. Materials used and location, alignment, grades and dimensions should be checked for compliance with the plans.

4. The earth excavation and the selecting, placing, spreading and compacting of the material in the embankment should be inspected frequently to insure that the specifications are met.

FINAL INSPECTION AND MEASUREMENTS

The final inspection by the technician should include sufficient profile and cross-section readings to insure that the height, top width, side slopes and other dimensions shown on the plans have been met. Elevations of the top of the trickle tube or principal spillway with relation to the control section of the spillway should be taken. Cross sections and profile of the emergency spillway should be surveyed to insure that it is constructed in accordance with the plan dimensions and left in the specified condition.

The final inspection should be made immediately after completion of the work and before the contractor moves his equipment from the site. Since this may not always be possible, training of local contractors to understand and meet construction requirements can save time of both the contractor and the technical staff.

RECORDS OF THE COMPLETED WORK

All observations and measurements made in connection with the final inspection of farm pond construction should be recorded in engineering loose-leaf or field notebooks and noted in red on the construction plans. A sample of the measurements required is shown in the Construction Check Notes, Figure 11-11. The notes should be filed in accordance with State

W. J. Sprinkle - Pond Const. Check — J. Scruggs ⊼ R. Bishop Φ — 1

9-28-63

Sta.	B.S.	H.I.	F.S./G.R.	Elev.	Planned Top Elev. 5% added	Notes
		Embankment				
BM 1	0.92	40.92		40.00		Nail in root 30" Oak 140' N.W. of N. end of dam. ℄
1+00			+5.4		35.5	5.2
+53			+5.2		35.7	20.4/51 13.1/30 9.5/20 4.9/6.5 4.8/0 5.1/6.5 9.4/20 12.9/30 21.6/54
2+00			+5.1		35.8	5.0
+32			+5.2		35.7	20.1/50 12.9/30 9.6/20 5.0/6.5 4.9/0 4.9/7.0 9.5/20 13.0/30 21.3/53
			9.36	31.56	31.60	Crest 18" C.M. trickle tube riser
			22.4	18.5	18.5	Invert 12" C.M. trickle tube barrel.
+59			+5.1		35.8	4.9
3+00			+5.2		35.7	19.6/49 12.8/30 9.4/20 4.9/6.5 4.8/0 5.0/7.0 9.2/20 12.7/30 20.8/52
+60			+5.7		35.2	5.4
	Earth Spillway				Planned Bottom Elev.	
0+48			+9.9		31.0	10.0

W. J. Sprinkle - Pond Const. Check — 2

Sta.	B.S.	H.I	F.S./G.R.	Elev.	Planned Bottom Elev.	Notes
		40.92				℄
0+70			+9.5		31.4	7.9/26.2 9.8/21 9.8/10 9.7/0 9.6/10 9.6/21 6.1/31.0
1+30			+8.3		32.6	8.4
+50	℄ Dam Control	Sec.	+8.3		32.6	5.9/25.2 8.3/21 8.4/10 8.3/0 8.4/10 8.5/22 5.0/35.9
+85			+9.5		31.4	9.7
2+25			+10.9		30.0	7.7/30.5 11.2/20 11.2/10 11.1/0 11.2/10 11.1/22 6.8/35.0
3+00			+13.4		27.5	13.5
BM 1				0.92	40.00	Check

Pond area cleared and all vegetation has been disposed of. A stand of fescue grass has been obtained on embankment, spillway and borrow areas. All other applicable specifications have been met.

Certified:

J. Scruggs
Conservation Aide

Note: All rod readings in excess of 13.0 ft. were taken by use of a hand level.

Figure 11–11 Construction check notes.

memorandums. Some State laws require a formal completion report and as-built plans.

12. POND AND RESERVOIR MAINTENANCE

A farm pond must be adequately maintained if its purposes are to be realized throughout its expected life. Severe damage to, or total failure of, dams and spillways have been caused by lack of maintenance. For these reasons, it is important that the owner carry out the measures described in the following paragraphs.

INSPECTION AND REPAIRS

Farm ponds should be inspected periodically, especially after heavy rains, to determine the need for minor repairs. Immediate repair often eliminates the need for more costly repairs later.

Rills on the slopes of the dam and washes in the earth spillway should be filled with suitable material and thoroughly compacted. These areas should be reseeded or resodded and fertilized as needed. Should the upstream face of the earthfill wash or slough due to wave action, protective devices such as booms or riprap should be installed. If there is seepage through or under the dam, an engineer should be consulted to recommend proper corrective measures.

The vegetative cover on the dam and earth spillway should be maintained by mowing and fertilizing when needed. Proper mowing prevents the formation of woody growth and tends to develop a cover and root system more resistant to runoff. Fences should be kept in good repair.

Appurtenances such as trickle tubes, trash racks, outlet structures, valves and watering troughs should be kept free of trash.

Burrowing animals may cause severe damage to farm pond dams or spillways. If such damage remains unrepaired it may lead to failure. A thick layer of sand or gravel on the fill discourages burrowing. Poultry netting can be used effectively, but it will rust out and need replacement. If these pests persist, aggressive trapping and poisoning should be undertaken.

SANITATION

It is desirable to keep the water in a farm pond as clean and unpolluted as possible. Unnecessary trampling by livestock should not be permitted. Where it is not practical to exclude livestock from a pond by fencing, small rocks or gravel should be used to pave the approaches to the water. Drainage from barn lots, feed yards, bedding grounds, outhouses, septic tanks, or other sources of contamination should be diverted from farm ponds. This is especially important where the water supply is to be used for harvesting ice, fish and wildlife development, or recreation.

In areas where surface waters encourage the breeding of mosquitoes, the pond should be stocked with top-feeding fish. Gambusia minnows are particularly effective. Where malaria prevails, aquatic growth and shoreline vegetation should not be permitted, and special precautions should be observed in the planning, construction, and operation of the pond. Most states in malarial sections have health regulations covering these precautions which should be followed.

In some areas the development of algae and other forms of plant life in reservoirs may become objectionable. Generally, these are harmless, but they may cause disagreeable tastes or odors, encourage bacterial development, and make the pond unsightly. Treatment with bluestone (copper sulfate) will check the development of algae. The usual dosage is 2 or 3 pounds per million gallons of water, well distributed throughout the reservoir. Overdosage may be harmful to both wildlife and livestock.

PART III - EXCAVATED PONDS

An excavated pond is the simplest type to construct and is the only type that can be constructed in relatively flat terrain. The fact that the capacity of these ponds is obtained almost solely from excavation limits their practical size. Since excavated ponds can be constructed to expose a minimum water surface area in proportion to volume, they are advantageous where evaporation losses are high and water is scarce. See Figures 11-12 and 11-13.

1. TYPES OF EXCAVATED PONDS

Excavated farm ponds may be divided into two types: those fed by surface runoff; and those fed by ground water aquifers, usually layers of sand and gravel. In some instances a pond may be fed from both of these sources.

2. LOCATION OF EXCAVATED PONDS

The location of excavated ponds depends on the purpose for which the water is to be used and on other factors discussed previously in this chapter.

Excavated ponds fed by surface runoff may be located on almost any type of topography. They are, however, most satisfactory and most commonly used in areas with comparatively flat terrain. A pond may be located in a broad natural drainageway or to one side of a drainageway if the runoff can be diverted into the pond. The low point of a natural depression is often a good location for an excavated pond. After the pond is filled, excess runoff escapes through natural drainageways. Thus, locations with favorable discharge conditions should be selected.

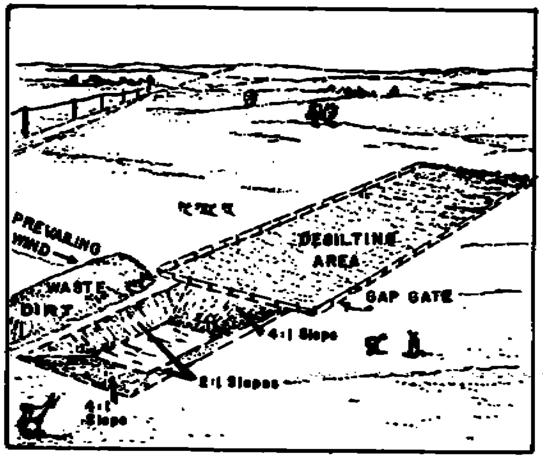
An excavated pond fed by ground water aquifers can be located only where shallow underground flow exists or where the permanent water table is within a few feet of the surface. See Figure 11-14.

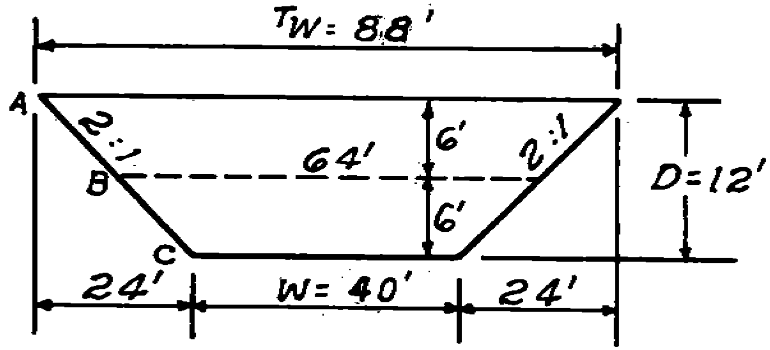
3. SOILS INVESTIGATION

Where the excavated pond is to be fed by surface runoff, relatively impervious soil at the site is essential to avoid excess seepage losses. Clays and silty clays extending below the planned reservoir depth are most desirable, and sites with sandy clays usually prove satisfactory. Sites where soils are porous or are underlain by sands or gravel should be avoided unless the owner is prepared to bear the expense of an artificial lining. Soils underlain by limestone containing crevices, sinks or channels should be avoided.

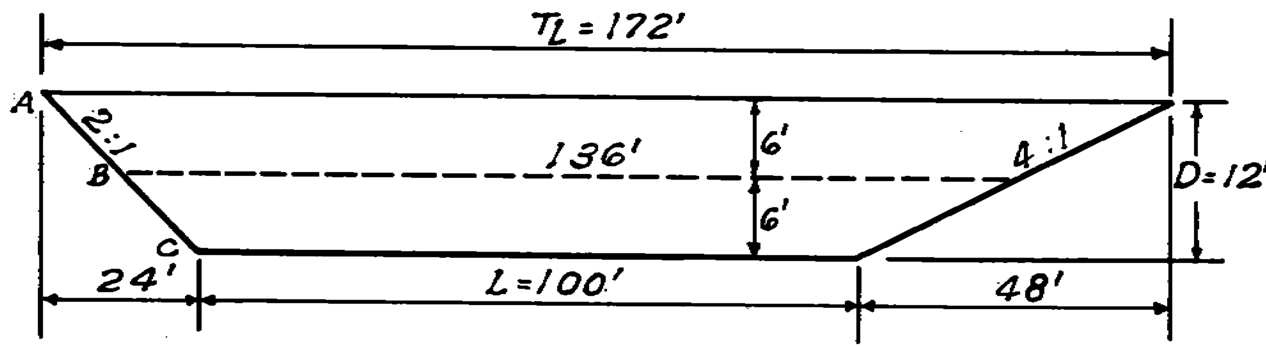
The performance of nearby existing ponds in a similar soil is a good indicator of the suitability of a proposed site. Such observations of existing ponds should be supplemented by subsurface investigations. Some indication of the permeability of the soil may be obtained by filling the test holes with water and observing the seepage characteristics of the material.

4-28467 Rev. 12-68





CROSS SECTION



LONGITUDINAL SECTION

(Not to Scale)

Figure 11–12 Excavated pond and typical sections. Note fenced desilting area above pond.

4-26467 Rev. 12-68

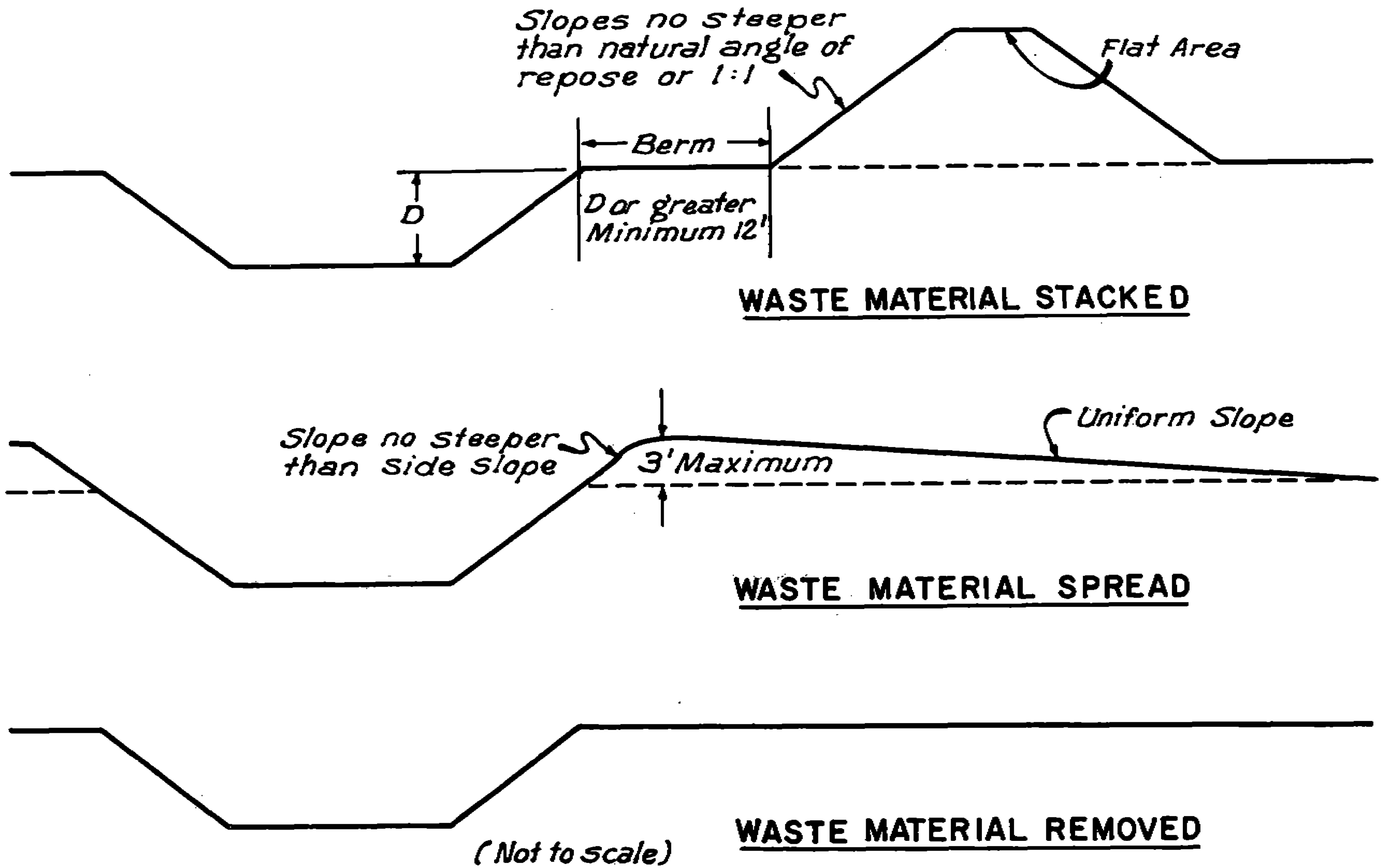


Figure 11–13 Cross sections of excavated pond showing methods of waste material disposal.

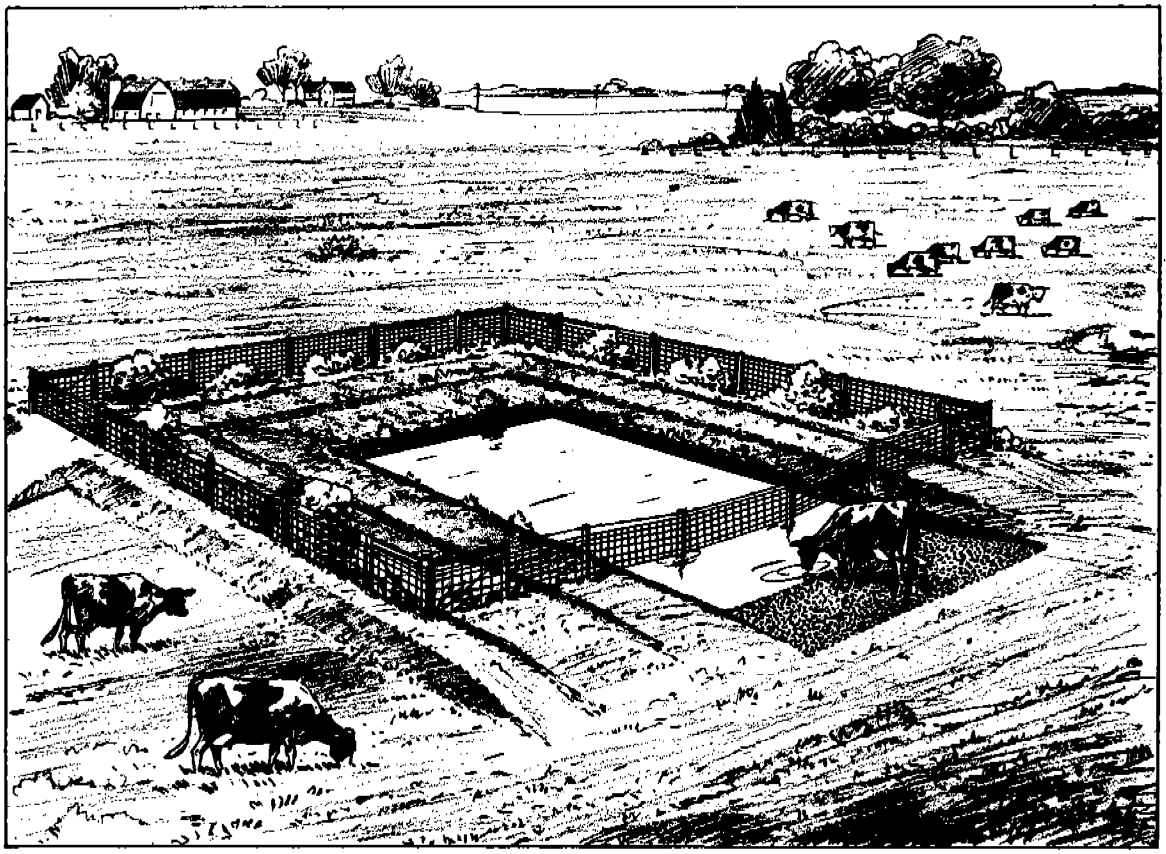


Figure 11-14 Excavated pond fed by ground water.

Sites proposed for aquifer-fed excavated ponds require a thorough subsurface investigation. Test holes should be bored to determine the existence and physical characteristics of the water-bearing material. The level to which water will rise in the test holes usually indicates the normal water level in the completed pond. The vertical distance between this level and the ground surface will determine the volume of excavation required that will not contribute to the usable capacity of the pond. From an economical standpoint, this vertical distance between water level and ground surface ordinarily should not exceed six feet. The rate at which the water rises in the test holes should also be observed. A rapid rate of rise indicates a high yielding aquifer. It also indicates that the water may be expected to return to its normal level within a short time after drawdown. A slow rate of rise in the test holes indicates a low-yielding aquifer and a slow rate of recovery in the pond. Observations of the test holes should be made during drier seasons to avoid being misled by a temporary high water table.

4. SPILLWAY AND INLET REQUIREMENTS

Where an excavated pond, fed by surface runoff, is located on sloping terrain a portion of the excavated material may be used to create a low dam around the lower end and sides of the pond to increase its capacity. In such cases, an earth spillway is required to pass excess storm runoff around the dam. The procedures for planning the spillway and providing for protection against erosion are the same as those previously discussed under Embankment Ponds.

Sometimes surface runoff must enter an excavated pond through a channel or ditch rather than through a broad shallow drainageway. In such cases the overfall from the ditch bottom to the bottom of the pond may create a serious erosion problem. Scouring will take place in the side slope of the pond and for a considerable distance upstream in the ditch. The resulting sediment will reduce the depth and capacity of the pond. Protection can best be provided by the use of one or more lengths of pipe of adequate size placed in the ditch, backfilled, and extended over the side slope of the excavation. The extended portion of the pipe may be cantilevered over timber supports. The required diameter of the pipe for an on-channel pond will depend on the peak rate of runoff that may be expected to occur once in ten years. The procedure for estimating peak rates of runoff is presented in Chapter 2 of this manual. Exhibit 11-7 shows the capacity of various sizes of pipe inlets. Where more than one pipe inlet is required, their combined capacity should equal or exceed the estimated peak rate of runoff.

For off-channel ponds, the pipe size should be such that it will divert from the channel sufficient runoff from normal annual rainfall or low flows to supply the reservoir. Here, duration of flow is of prime importance.

Off-channel ponds also can be filled by pumping from the stream during storm flows. The pump must be large enough to fill the pond before stream flow returns to normal.

In areas where a considerable amount of silt is carried by the inflowing water a grassed filter strip should be provided in the drainageway immediately above the pond. The width of this strip should be equal to or somewhat greater than the width of the pond and its length should be 100 feet or more. The perennial grasses used should create a high "n" value so that flows through the grass will be reduced in velocity to a point where the silt will settle out and the water entering the pond will be relatively silt-free. See small insert, Figure 11-12.

5. PLANNING AN EXCAVATED POND

SHAPE AND CAPACITY

Excavated ponds may be constructed to almost any shape desired, however, a rectangular shape usually is the most convenient for excavating equipment.

The required capacity of an excavated pond fed by surface runoff is determined by the purpose for which water is needed and the amount of inflow that can be expected. These factors have been discussed under Embankment Ponds.

The required capacity of an excavated pond fed by an underground water-bearing layer is difficult to determine since the estimated rate of inflow into the pond can rarely be estimated with reasonable accuracy. For this reason the pond should be constructed in such manner that it can be enlarged if the original capacity proves inadequate.

SELECTING POND DIMENSIONS

The selected dimensions of an excavated pond will depend upon the required capacity. Excavated ponds fed by surface runoff should have a depth equal to or greater than the minimum required by State Standards and Specifications. Where an excavated pond is fed from ground water, the depth should extend well into the water-bearing material. The maximum depth will depend on the climatic conditions, the nature of the material to be excavated, and the type of equipment to be used in excavating the pond.

The width of an excavated pond will not ordinarily be limited, except that the type and size of the excavating equipment may become a limiting factor. For example, if a dragline is used the length of the boom will determine the maximum width of excavation that can be made with proper placement of the waste material.

The minimum length of the pond should be that needed to obtain the required pond capacity. However, this length may need to be increased to meet the needs of the excavating equipment, such as a carryall.

The side slopes of an excavated pond should not be steeper than the natural angle of repose of the material being excavated. This angle will vary with different soils, but in most cases the side slopes should be flatter than 1:1.

Where the water is to be used for watering livestock, a ramp with a slope of 4:1, or flatter, should be provided at one or both ends for access. Regardless of the intended use of the water, these flat slopes at the ends of the pond are necessary when tractor-pulled scrapers or bulldozers are used for construction.

ESTIMATING THE VOLUME OF AN EXCAVATED POND

After the dimensions and side slopes of the pond have been selected, it is usually necessary to prepare an estimate of the volume of excavation. Such an estimate determines the cost of the pond and serves as a basis for payment if the work is done by contract.

The volume of excavation required can be estimated with sufficient accuracy by use of the prismoidal formula:

$$V = \frac{(A + 4B + C)}{6} \times \frac{D}{27}$$, where:

V = Volume of excavation, in cubic yards

A = Area of the excavation at the ground surface, in square feet

B = Area of the excavation at the mid-depth point (1/2 D), in square feet

C = Area of the excavation at the bottom of the pond, in square feet.
D = Average depth of the pond, in feet
27 = Factor converting cubic feet to cubic yards

As an example, assume a pond with a depth, D, of 12 feet; a bottom width, W, of 40 feet, and a bottom length, L, of 100 feet as shown in Figure 11-12.

The side slope at the ramp end is 4:1 and the remaining slopes are 2:1. The volume excavation, V, is computed as follows:

Top length	= 12(2) + 12(4) + 100 = 172 feet	
Top width	= 12 (2)(2) + 40 = 88 feet	
	A = 88 x 172 =	15,136 square feet
Mid-length	= 6(2) + 6 (4) + 100 = 136 feet	
Mid-width	= 6(2)(2) + 40 = 64 feet	
	4B = 4(64 x 136) =	34,816 square feet
	C = 40 x 100 =	4,000 square feet
	(A + 4B + C) =	53,952 square feet

Then $V = \frac{53,952}{6} \times \frac{12}{27} = 3,996$ cubic yards (or 4,000 cubic yards)

Assuming that the normal water level in the pond is at the ground surface, the volume of water that can be stored in the pond is 4,000 cu. yds. x .00062, or 2.48 acre feet. To convert to gallons multiply 4,000 cu. yds. by 202.0 to get 808,000 gallons. The same procedure is used to compute the volume of water that can be stored in the pond when the normal water level is below the ground surface. In this case, the value assigned to the depth, D, is the actual depth of water in the pond rather than the depth of excavation.

DISPOSAL OF WASTE MATERIAL

The placement or disposal of the excavated material should be planned in advance of construction. Proper disposal will prolong the useful life of the pond, improve its appearance and facilitate maintenance and establishment of vegetation. The waste material may be stacked, spread, or removed from the site as conditions warrant.

The waste material, when not removed from the site, should be placed in a manner that its weight will not endanger the stability of the pond side slopes and the rainfall will not wash the material back into the pond. Stacked material should be placed in a uniform bank with side slopes no steeper than the natural angle of repose of the soil. A berm with a width equal to the depth of the pond, but not less than 12 feet should be left between the toe of the waste bank and the edge of the pond. In the case of large ponds, it is often desirable to stack the waste material along two sides of the pond to reduce the height of the banks. In the Northern Plains the waste banks may be placed on the windward side of the pond to serve as a snow fence for collecting drifts in the pond. See Figure 11-12.

Banks placed in this manner may also reduce evaporation losses by breaking the force of prevailing winds across the pond.

Spreading the waste material along one or both sides of a pond has several advantages. The pressure on the excavated slopes is reduced, establishment of vegetation is enhanced, and the general appearance of the pond is improved. The waste material should be spread to a height of no more than 3 feet with the surface graded to a uniform slope away from the pond. The pond side slope of the spread material should be no steeper than the excavated slopes. Rocky, infertile, or otherwise unproductive material, should not be spread over productive areas. Sometimes the waste material may be used for filling nearby low areas in a field or in the construction of farm roads.

Figure 11-13 shows cross sections of a pond illustrating the methods of placement and disposal of waste material.

6. EXCAVATED POND CONSTRUCTION

The pond site and waste areas should first be cleared of all woody vegetation. The limits of the excavation and spoil placement areas should be staked, and the depth of cut from the ground surface to the pond bottom should be indicated on the stakes.

Excavation and the placement of the waste material are the principal items of work required in the construction of this type of pond. The type of equipment used will depend on climate and physical conditions at the site, and on the equipment available.

In areas of low rainfall almost any type of equipment may be used and the choice of type is determined by availability. The most commonly used are tractor-pulled wheeled scrapers, draglines, and bulldozers. Due to its inefficiency in transporting material, the use of a bulldozer for excavation is usually limited to relatively small ponds.

In high-rainfall areas and in areas where a ground water table exists within the limits of excavation, the dragline is most commonly used since it can operate satisfactorily in water. The dragline is used exclusively for ponds fed by ground water aquifers.

The excavation should be made and the waste material placed as near to the staked lines and grades as skillful operation of the equipment will permit. Where the pond is constructed by a dragline, other types of equipment may be required to shape or spread the waste material. Bulldozers and graders are commonly used for this purpose.

Excavated ponds should be protected against erosion damage by a good cover of sod-forming grasses on the side slopes of the pond above the normal water level, the berms, the waste banks, and the emergency spillway, where required.

PART IV - SEALING PONDS AND RESERVOIRS

1. SEALING METHODS

GENERAL

Excessive seepage losses in farm ponds usually are due to the selection of a site where the soils are too permeable to hold water. This may be the result of inadequate site investigations in the planning stage. However, the need for water may be so important as to justify the selection of a permeable site. In such cases, plans for reducing seepage losses by sealing should be part of the design.

The problem of reducing seepage losses is one of reducing the permeability of the soils to a point where the losses become tolerable. Losses may be reduced by the methods discussed below, the choice of which will depend largely on the proportions of coarse grained sand and gravel and fine grained silt and clay in the soil. A thorough investigation of the materials to be sealed should be made by a soils scientist before the method of sealing is selected. In some cases it may be necessary to have a laboratory analysis of the materials.

SEALING BY COMPACTION ALONE

Pond areas containing a high percentage of coarse grained material can be made relatively impervious by compaction alone if the material is well graded from small gravel or coarse sand to fine sand, clay, and silt. This method of sealing is the least expensive of those presented in this chapter, but its use is limited to the soil conditions described.

The pond area should be cleared of all trees and other vegetation and all stump holes, crevices, and similar areas should be filled with relatively impervious material. The soil should be scarified to a depth of 8 to 10 inches with a disk, roto-tiller, pulverizer or similar equipment and all rocks and tree roots should be removed. The loosened soil should be rolled under optimum moisture conditions to a dense, tight layer with four to six passes of a sheepsfoot roller.

The thickness of the compacted seal should not be less than 8 inches for impoundments up to 10 feet in depth. Since seepage losses vary directly with the depth of water impounded, the thickness of the compacted seal should be increased proportionately when the depth of water exceeds 10 feet. This will require compacting the soil in two or more layers not exceeding 8 inches in thickness over that portion of the pond where the water depth exceeds 10 feet. In these cases the top layer or layers of soil will have to be removed and stockpiled while the bottom layer is being compacted.

USE OF CLAY BLANKETS

Pond areas containing high percentages of coarse grained soils but lacking sufficient amounts of clay to prevent high seepage losses can be sealed by blanketing. The blanket should cover the entire area over which water is to be impounded. It should consist of material containing a wide range of particle sizes varying from small gravel or coarse sand to fine sand and clay in the desired proportions. Such material should contain approximately 20 percent by weight of clay particles.

The thickness of the blanket will depend on the depth of water to be impounded. The minimum thickness should be 12 inches for all depths of water up to 10 feet. The minimum should be increased by 2 inches for each foot of water over 10 feet. The construction procedure is similar to that described previously for constructing earth embankments.

Clay blankets require protection from cracking that results from drying or freezing and thawing. A cover of gravel, 12 to 18 inches thick, placed over the blanket may be used for this purpose. Blanketed areas should be protected by a cantilevered pipe or rock riprap where flow into the pond is concentrated.

SEALING WITH BENTONITE

Seepage losses in well graded coarse grained soils may be reduced by the addition of Bentonite. Bentonite is a fine textured colloidal clay that will absorb several times its own weight in water. At complete saturation it will swell from 8 to 15 times its original volume. When Bentonite is mixed in the correct proportions with the coarse grained material, and the mixture is thoroughly compacted and saturated, the particles of Bentonite will fill the pores in the material and make it nearly impervious. A laboratory analysis of the material is essential to determine the amount of Bentonite that should be applied per unit of area. Rates of application range from 1 to 3 pounds per square foot, depending on site conditions. Bentonite, upon drying, will return to its original volume and leave cracks in the pond area. For this reason, Bentonite is not recommended for ponds where a wide fluctuation in the water level is expected.

As with other methods, the pond area should be cleared of all vegetation and all holes, crevices and areas of exposed gravel should be filled or covered with suitable compacted material.

The soil moisture level in the area to be treated should be optimum for good compaction. If the area is found to be too wet, sealing operations should be postponed until moisture conditions are satisfactory. If the material is too dry, water should be added by sprinkling.

The Bentonite should be spread uniformly over the area to be treated at the rate determined by the laboratory analysis. The Bentonite is then thoroughly mixed with the soil to a depth of at least six inches with a roto-tiller, disk, or similar equipment. The area should then be compacted with four to six passes of a sheepsfoot roller.

Since considerable time may elapse between application of the Bentonite and the filling of the pond it may be necessary to protect the treated area by mulching with straw or hay anchored to the surface by the final passes of the sheepsfoot roller. Treated areas subject to inflow should be protected by riprap or other mechanical means.

TREATMENT WITH CHEMICAL ADDITIVES

Excessive seepage losses often occur in fine grained clay soils because of the arrangement of the clay particles which form a honeycomb structure. Such soils are said to be aggregated and have a relatively high permeability rate. The application of small amounts of certain chemicals to these aggregates may result in collapse of the open structure and rearrangement of the clay particles. The chemicals used are called dispersing agents.

For chemical treatment to be effective, the soils in the pond area should contain more than 50 percent of fine grained material (silt and clay finer than .074 mm diameter) and at least 15 percent of clay finer than .002 mm diameter. The soils should contain less than 0.5 percent soluble salts (based on dry soil weight). Chemical treatment is not effective in coarse grained soils.

While there are many soluble salts that meet the requirement of a dispersing agent, sodium polyphosphates are most commonly used. Tetrasodium Pyrophosphate (TSPP) and Sodium Tripolyphosphate (STPP) are most effective. These dispersants should be finely granular with 95 percent passing a No. 30 sieve and less than 5 percent passing a No. 100 sieve. They usually are applied at a rate of from 0.05 to 0.10 pounds per square foot. Sodium chloride, which is less effective, is applied at a rate of from 0.20 to 0.33 pounds per square foot. A laboratory analysis of the soils in the pond area is essential to determine which of these dispersing agents will be most effective and the rate at which it should be applied.

The dispersing agent is mixed with the surface soil and compacted to form a blanket. For depths of water up to 8 feet, the blanket thickness should be at least 6 inches. For depths of water greater than 8 feet, the blanket should be 12 inches thick treated in two 6-inch lifts. A minimum thickness of 12 inches is recommended for all areas in the range of water surface fluctuation.

The area to be treated should be cleared of all vegetation and trash. Rock outcrops and other exposed areas of highly permeable material should be covered with from 2 to 3 feet of fine grained soil. This material should then be thoroughly compacted. In cavernous limestone areas, the success or failure of the seal may depend upon the thickness and compaction of this initial blanket.

The soil moisture level in the area to be treated should be near optimum for compaction down to a depth of 12 inches. If the soil is too wet treatment should be postponed. Polyphosphates release water from the soil and the job could easily become too wet to handle. If the soil is too dry, water should be added by sprinkling.

The dispersing agent should be applied uniformly over the pond area at a rate determined by the laboratory analysis. The dispersant may be applied with a seeder, drill, fertilizer spreader or by hand broadcasting.

The dispersing agent should be thoroughly mixed into each 6-inch layer with a disk, roto-tiller, pulverizer or similar equipment. Operating the mixing equipment in two directions will produce best results. Each chemically treated layer should be thoroughly compacted with 4 to 6 passes of a sheepsfoot roller.

The treated blanket should be protected from puncture by livestock trampling. Areas near the normal waterline should also be protected from erosion by covering with a 12- to 18-inch blanket of gravel or other suitable material. Areas where inflow into the pond is concentrated should be protected with riprap or other erosion resistant materials such as concrete or metal pipe.

Due to rapid technologic advancements, new chemical additives are being developed constantly. Some of these may prove useful in reducing seepage losses.

USE OF FLEXIBLE MEMBRANES

Another method of reducing excessive seepage losses is the use of flexible membranes of Polyethylene, vinyl and butyl rubber.

Thin films of these materials are structurally weak but, if kept intact, they are almost completely watertight. Polyethylene films are less expensive and have better aging properties than vinyl. Vinyl is more resistant to impact damage and is readily seamed and patched with a solvent cement. Polyethylene can be joined or patched only by heat sealing. Butyl rubber can be joined or patched with a special cement.

These thin films must be protected from mechanical damage if they are to be serviceable. All polyethylene and vinyl rubber membranes should have a cover of earth or earth and gravel not less than 6 inches thick. Butyl rubber membranes need to be covered only in areas subject to travel by livestock. In these areas, a minimum cover of 9 inches should be used over all types of membranes. The bottom 3 inches of cover should not be coarser than silty sand.

All membranes should be of a quality that meets or exceeds the minimum requirements shown in the State Standards and Specifications for Pond Sealing or Lining. The minimum normal thickness should equal or exceed the value shown below for the soil material being covered and the type of membrane used.

Soil Material Not Coaser than:	Polyethylene	Vinyl	Butyl Rubber
Sands, Clean or Silty	8 mil.	8 mil.	15 mil.
Gravels, Clean, Silty or Clayey	15 mil.	15 mil.	30 mil.

The area to be lined should be drained and allowed to dry until the surface is firm and will support the men and equipment that must travel over it during installation of the lining.

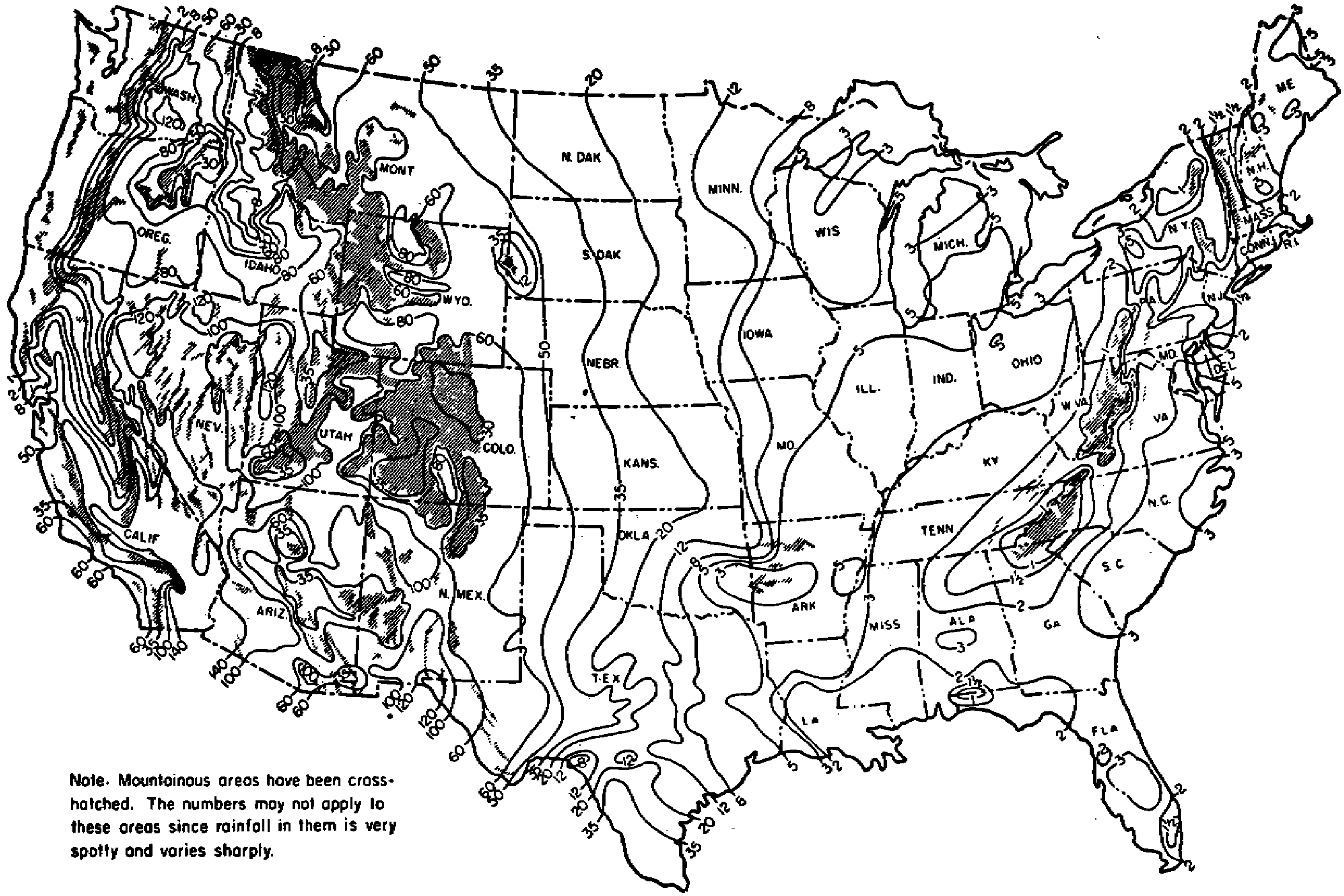
The pond area should be cleared of all vegetation and all roots, sharp stones or other objects that might tend to puncture the film. If the material over which the lining is to be placed is stony or of very coarse texture, it should be covered with a cushion layer of fine textured material before the lining is placed. All banks, side slopes and fills within the area to be lined should be uniformly sloped no steeper than 1:1 for exposed lining and 3:1 for covered lining. The cover material may slide on the lining if placed on steeper slopes.

Certain plants penetrate vinyl and polyethylene film. For this reason, it is desirable to sterilize the subgrade with chemicals, particularly the side slopes where nutgrass, Johnsongrass, quackgrass, and other plants having a high penetrating power are present. Sterilization is not required where butyl rubber membranes are used.

The top edges of the lining should be anchored in a trench excavated completely around the area to be lined at the planned elevation of the top of the lining. The trench should be 8 to 10 inches deep and about 12 inches wide. The lining should then be anchored by burying 8 to 12 inches of the lining in the anchor trench and securing it with compacted backfill.

The linings are usually laid in sections or strips with a 6-inch overlap for seaming. Vinyl and butyl rubber linings should be laid smooth but in a loose state. Polyethylene should have up to 10 percent slack. Extreme care must be exercised in handling to avoid puncture.

The materials used to cover the membrane should be free of large clods, sharp rocks, sticks and other objects that would puncture the lining. The cover should be placed to the specified depth without damage to the membrane.



Note. Mountainous areas have been cross-hatched. The numbers may not apply to these areas since rainfall in them is very spotty and varies sharply.

Exhibit 11–1 Guide for estimating approximate acres of drainage area required per acre-foot of storage in a farm pond.

TABLE 1
PERMISSIBLE VELOCITIES FOR VEGETATED SPILLWAY 1/
(SI Units)

	Permissible velocity 2/			
	Erosion resistant 3/ soils		Easily erodible 4/ soils	
	Slope of exit channel		Slope of exit channel	
	pct 0-5	pct 5-10	pct 0-5	pct 5-10
	m/s	m/s	m/s	m/s
Bermudagrass Bahiagrass	2.4	2.1	1.8	1.5
Buffalograss Kentucky bluegrass Smooth bromegrass Tall fescue Reed Canarygrass	2.1	1.8	1.5	1.2
Sod forming grass-legume mixtures	1.5	1.4	1.2	0.9
Lespedeza sericea Weeping lovegrass Yellow bluestem Native grass mixtures	1.1	1.1	0.8	0.8

1/ SCS-TP-61
2/ Increase values 10 percent when the anticipated average use of the spillway is not more frequent than once in 5 years or 25 percent when the anticipated average use is not more frequent than once in 10 years.
3/ Those with a higher clay content and higher plasticity. Typical soil textures are silty clay, sandy clay, and clay.
4/ Those with a high content of fine sand or silty and lower plasticity or non-plastic. Typical soil textures are fine sand, silt, sandy loam, and silty loam.

TABLE 2. -- Guide to selection of vegetal retardance
(SI Units)

Stand	Average length of vegetation	Degree of retardance	Stand	Average length of vegetation	Degree of retardance
	cm			cm	
Good	Longer than 76	A	Fair	Longer than 76	B
	28 to 61	B		28 to 61	C
	15 to 25	C		15 to 25	D
	5 to 15	D		5 to 15	D
	less than 5	E		less than 5	E

TABLE 1
PERMISSIBLE VELOCITIES FOR VEGETATED SPILLWAY 1/
(English Units)

	Permissible velocity 2/			
	Erosion resistant 3/ soils		Easily erodible 4/ soils	
	Slope of exit channel		Slope of exit channel	
	pct 0-5	pct 5-10	pct 0-5	pct 5-10
	ft/s	ft/s	ft/s	ft/s
Bermudagrass Bahiagrass	8	7	6	5
Buffalograss Kentucky bluegrass Smooth bromegrass Tall fescue Reed Canarygrass	7	6	5	4
Sod forming grass-legume mixtures	5	4	4	3
Lespedeza sericea Weeping lovegrass Yellow bluestem Native grass mixtures	3.5	3.5	2.5	2.5

1/ SCS-TP-61
2/ Increase values 10 percent when the anticipated average use of the spillway is not more frequent than once in 5 years or 25 percent when the anticipated average use is not more frequent than once in 10 years.
3/ Those with a higher clay content and higher plasticity. Typical soil textures are silty clay, sandy clay, and clay.
4/ Those with a high content of fine sand or silty and lower plasticity or non-plastic. Typical soil textures are fine sand, silt, sandy loam, and silty loam.

TABLE 2. -- Guide to selection of vegetal retardance
(English Units)

Stand	Average length of vegetation	Degree of retardance	Stand	Average length of vegetation	Degree of retardance
	in			in	
Good	Longer than 30	A	Fair	Longer than 30	B
	11 to 24	B		11 to 24	C
	6 to 10	C		6 to 10	D
	2 to 6	D		2 to 6	D
	less than 2	E		less than 2	E

Example #1 (SI Units) for use of Exhibit 11-2 where only one retardance is used for capacity and stability.

Given:

$Q = 2.5\ m^3/s$ (Determined from NEFM Ch-2)
So = 4% (Determined from profile or to be excavated).
L = 15.3 m

Spillway to be excavated in an erosion resistant soil and planted to a sod forming grass-legume mixture. After establishment, a good stand averaging from 15 to 25 cm in height is expected.

Required:

Permissible velocity (V), width of spillway (b) and depth of water in the reservoir above the crest (Hp).

Solution:

From Table 1 sod forming grass-legume mixtures-permissible velocity V = 1.5 m/s. From Table 2 average length of vegetation 15 to 25 cm Retardance C.

For C Retardance enter Table 3-C from left at maximum velocity V = 1.5 m/s, 4% slope is in the slope range of 1-6 with q of .28 $m^3/s/m$. Then:

$$b = \frac{Q}{q} = \frac{2.5\ m^3/s}{0.28\ m^3/s/m} = 8.9\ m$$

Hp for L of 15.3 = 0.43 m

Erosion Resistant Soil Yes No
Cover: Type grass-legume mixture
Condition: good
Height: 15 to 25 cm
Slope: 4%

Q m^3/s	V max m/s Table 1	Retardance Table 2 stability	capacity	L m	q $m^3/s/m$	b m stability	Hp m capacity	So Slope Min.	Range Max.
2.5	1.5	C	C	15.3	0.28	8.9	0.43	1	6

Sample form for recording solution to example where one retardance is used for stability and capacity.

Exhibit 11-2

Example #1 (English Units) for use of Exhibit 11-2 where only one retardance is use for capacity and stability.

Given:

$Q = 87\ ft^3/s$ (Determined from NEFM Ch-2).
So = 4% (Determined from profile or to be excavated).
L = 50 ft

Spillway to be excavated in an erosion resistant soil and planted to a sod forming grass-legume mixture. After establishment, a good stand averaging from 6 to 10 inches in height is expected.

Required:

Permissible velocity (V), width of spillway (b) and depth of water in the reservoir above the crest (Hp).

Solution:

From Table 1 sod forming grass-legume mixtures permissible velocity V = 5 ft/s. From Table 2 average length of vegetation 6 to 10 inches. Retardance C.

For C Retardance enter Table 3-C from left at maximum velocity V = 5 ft/s, 4% slope is in the slope range of 1-6 with q of 3 $ft^3/s/ft$. Then:

$$b = \frac{Q}{q} = \frac{87\ ft^3/s}{3\ ft^3/s/ft} = 29\ ft.$$

Hp for L of 50 = 1.4 ft.

Erosion Resistant Soil: Yes No
Cover: Type grass-legume mixture
Condition: good
Height: 6 to 10 inches
Slope: 4%

Q ft^3/s	V max ft/s Table 1	Retardance (Table 2) stability	capacity	L ft.	q $ft^3/s/ft$	b ft stability	Hp ft capacity	So Slope Range Min.	Max.
87	5	C	C	50	3	29	1.4	1	6

Sample form for recording solution to example where one retardance is used for stability and capacity.

Exhibit 11-2

Example #2 (SI Units) for use of Exhibit 11-2 where one retardance is used for stability and another is used for capacity.

Given:

$Q = 2.8\ m^3/s$ (Determined from NEFM Ch-2).
So = 8% (Determined from profile or to be excavated).
L = 7.6 m

Spillway to be excavated in a easily erodible soil and planted to bahiagrass with a good stand of 28 to 61 cm expected.

Required:

Permissible velocity (V), width of spillway (b) and depth of water in the reservoir above the crest (Hp).

Solution:

From Table 1: Determine permissible velocity for bahiagrass in a easily erodible soil with 8% slope. V = 1.5 m/s.

From Table 2: (1) Select retardance to be used for stability during an establishment period with a good stand of vegetation of 5 to 15 cm. (Retardance = D).

(2) Select retardance to be used for capacity for good stand of vegetation with a length of 28 to 61 cm. (Retardance = B).

From Table 3-D: Enter from left at maximum velocity V = 1.5 m/s a slope of 8% is in the range for: $Q = 0.19\ m^3/s/m$

$$b = \frac{Q}{q} = \frac{2.8\ m^3/s}{0.19\ m^3/s/m} = 15\ m \quad \text{(stability)}$$

From Table 3-B: Enter at $q = 0.19\ m^3/s/m$ find Hp for L of 7.6 m. Hp = 0.43 m. (capacity)

Erosion Resistant Soil: Yes No
Cover: Type Bahiagrass
Condition: good
Heights Max: 28 to 61 cm Min. 5 to 15 cm
Slope: 8%

Q m^3/s	V max m/s Table 1	Retardance (Table 2) stability	capacity	L (m)	q $m^3/s/m$	b (m) stability	Hp (m) capacity	So Slope Range Min.	Max.	Adequate
2.8	1.5	D		7.6	0.28			1	4	No
		D			0.19	15		1	9	Yes
			B		0.19		0.43	1	8	Yes

Sample form for recording solution to Example where one retardance is used for stability and another is used for capacity.

Exhibit 11-2

Example #2 (English Units) for use of Exhibit 11-2 where one retardance is used for stability and another is used for capacity.

Given:

$Q = 100\ ft^3/sec$ (Determined from NEFM Ch-2).
So = 8% (Determined from profile or to be excavated).
L = 25 ft

Spillway to be excavated in a easily erodible soil and planted to bahiagrass with a good stand of 11 to 24 inches expected.

Required:

Permissible velocity (V), width of spillway (b) and depth of water in reservoir above the crest (Hp).

Solution:

From Table 1: Determined permissible velocity for bahiagrass in a easily erodible soil with 8% slope. V = 5 ft/s.

From Table 2: (1) Select retardance to be used for stability during an establishment period with a good stand of vegetation of 2 to 6 inches. (Retardance = D).

(2) Select retardance to be used for capacity for good stand of vegetation with a length of 11 to 24 inches. (Retardance = B).

From Table 3-D: Enter from left at maximum velocity V = 5 ft/s a slope of 8% is in the range for: $Q = 2\ ft^3/s/ft$

$$b = \frac{Q}{q} = \frac{100\ ft^3/s}{2\ ft^3/s/ft} = 50\ ft \qquad \text{(stability)}$$

From Table 3-B: Enter at $q = 2\ ft^3/s/ft$ find Hp for L of 25 ft
Hp = 1.4 ft. (capacity)

Erosion Resistant Soil Yes No
Cover: Type Bahiagrass
Condition good
Height: Max: 11 to 24 inches Min. 2 to 6 inches
Slope: 8%

Q ft^3/s	V mas ft/s Table 1	Retardance Table 2 stability	Retardance Table 2 capacity	L ft	q $ft^3/s/ft$	b ft stability	Hp ft capacity	So Slope Range Min.	So Slope Range Max.	Adequate
100	5	D		25	3			1	4	No
		D			2	50		1	9	Yes
			B		2		1.4	1	8	Yes

Sample form for recording solution to example where one retardance is used for stability and another is used for capacity.

Exhibit 11-2

Table 3-A.--H_p and slope range for discharge, velocity, and crest length, Retardance A

(SI Units)

Max. Velocity V	Discharge q	H_p L(m) 7.6	15.3	30.5	61	Slope Range Min.	Max.
m/s	$m^3/s/m$	m	m	m	m	pct	
0.9	0.28	0.70	0.76	0.82	0.94	1	11
1.2	.37	.70	0.76	.85	0.94	1	12
1.2	.46	.75	0.79	.88	0.98	1	7
1.5	.56	.79	0.83	.91	1.01	1	9
1.8	.65	.82	0.85	.94	1.07	1	12
2.1	.92	.91	0.98	1.04	1.16	1	9
2.4	1.16	1.01	1.07	1.13	1.25	1	10

Table 3-A.--H_p and slope range for discharge, velocity, and crest length, Retardance A

(English Units)

Max. Velocity V	Discharge q	H_p L(ft) 25	50	100	200	Slope Range Min.	Max.
ft/s	$ft^3/s/ft$	ft	ft	ft	ft	pct	
3	3	2.3	2.5	2.7	3.1	1	11
4	4	2.3	2.5	2.8	3.1	1	12
4	5	2.5	2.6	2.9	3.2	1	7
5	6	2.6	2.7	3.0	3.3	1	9
6	7	2.7	2.8	3.1	3.5	1	12
7	10	3.0	3.2	3.4	3.8	1	9
8	12.5	3.3	3.5	3.7	4.1	1	10

Table 3-B.--H_p and slope range for discharge, velocity, and crest length, Retardance B

(SI Units)

Max. Velocity V	Discharge q	H_p L(m) 7.6	15.3	30.5	61	Slope Range Min.	Max.
m/s	$m^3/s/m$	m	m	m	m	pct	
0.6	0.09	0.37	0.43	0.46	0.55	1	12
0.6	.116	.39	.43	.49	.58	1	7
0.9	.14	.39	.46	.52	.58	1	12
0.9	.19	.43	.46	.52	.58	1	8
1.2	.28	.48	.52	.58	.67	1	9
1.5	.37	.55	.58	.64	.73	1	8
1.8	.46	.58	.64	.70	.76	1	10
2.1	.56	.64	.67	.73	.82	1	11
2.4	.65	.67	.73	.79	.88	1	12

Table 3-B.--H_p and slope range for discharge, velocity, and crest length, Retardance B

(English Units)

Max. Velocity V	Discharge q	H_p L(ft) 25	50	100	200	Slope Range Min.	Max.
ft/s	$ft^3/s/ft$	ft	ft	ft	ft	pct	
2	1	1.2	1.4	1.5	1.8	1	12
2	1.25	1.3	1.4	1.6	1.9	1	7
3	1.5	1.3	1.5	1.7	1.9	1	12
3	2	1.4	1.5	1.7	1.9	1	8
4	3	1.6	1.7	1.9	2.2	1	9
5	4	1.8	1.9	2.1	2.4	1	8
6	5	1.9	2.1	2.3	2.5	1	10
7	6	2.1	2.2	2.4	2.7	1	11
8	7	2.2	2.4	2.6	2.9	1	12

Table 3-C.--H_p and slope range for discharge, velocity, and crest length, Retardance C

(SI Units)

Max. Velocity V	Discharge q	H_p L(m) 7.6	15.3	30.5	61	Slope Range Min.	Max.
m/s	$m^3/s/m$	m	m	m	m	pct	
0.6	0.046	0.21	0.24	0.27	0.34	1	6
0.6	.09	.27	.30	.34	.40	1	3
0.9	.116	.27	.30	.37	.40	1	6
1.2	.14	.30	.34	.37	.43	1	12
1.2	.19	.34	.37	.43	.49	1	7
1.5	.28	.40	.43	.49	.55	1	6
1.8	.37	.46	.49	.55	.61	1	12
2.4	.46	.52	.55	.61	.67	1	12
2.7	.56	.55	.61	.64	.73	1	12
2.7	.65	.61	.64	.70	.76	1	10
3.0	.70	.64	.67	.73	.79	1	12

Table 3-C.--H_p and slope range for discharge, velocity, and crest length, Retardance C

(English Units)

Max. Velocity V	Discharge q	H_p L(ft) 25	50	100	200	Slope Range Min.	Max.
ft/s	$ft^3/s/ft$	ft	ft	ft	ft	pct	
2	0.5	0.7	0.8	0.9	1.1	1	6
2	1	.9	1.0	1.2	1.3	1	3
3	1.25	.9	1.0	1.2	1.3	1	6
4	1.5	1.0	1.1	1.2	1.4	1	12
4	2	1.1	1.2	1.4	1.6	1	7
5	3	1.3	1.4	1.6	1.8	1	6
6	4	1.5	1.6	1.8	2.0	1	12
8	5	1.7	1.8	2.0	2.2	1	12
9	6	1.8	2.0	2.1	2.4	1	12
9	7	2.0	2.1	2.3	2.5	1	10
10	7.5	2.1	2.2	2.4	2.6	1	12

Table 3-D.--H_p and slope range for discharge, velocity, and crest length, Retardance D

(SI Units)

Max. Velocity V	Discharge q	H_p L(m) 7.6	15.3	30.5	61	Slope Range Min.	Max.
m/s	$m^3/s/m$	m	m	m	m	pct	
0.6	0.046	0.18	0.21	0.24	0.27	1	6
0.9	.09	.24	.27	.31	.34	1	6
0.9	.116	.24	.27	.31	.37	1	4
1.2	.116	.24	.27	.31	.37	1	10
1.2	.19	.31	.34	.40	.43	1	4
1.5	.14	.27	.31	.37	.40	1	12
1.5	.19	.31	.37	.40	.43	1	9
1.5	.28	.37	.40	.46	.52	1	4
1.8	.23	.34	.37	.43	.46	1	11
1.9	.28	.37	.40	.46	.52	1	7
2.1	.28	.37	.40	.46	.52	1	12
2.1	.37	.43	.46	.52	.58	1	7
2.4	.37	.43	.46	.52	.58	1	12
2.4	.46	.48	.52	.58	.61	1	8
3.0	.56	.55	.58	.61	.67	1	12

Table 3-D.--H_p and slope range for discharge, velocity, and crest length, Retardance D

(English Units)

Max. Velocity V	Discharge q	H_p L(ft) 25	50	100	200	Slope Range Min.	Max.
ft/s	$ft^3/s/ft$	ft	ft	ft	ft	pct	
2	0.5	0.6	0.7	0.8	0.9	1	6
3	1	.8	.9	1.0	1.1	1	6
3	1.25	.8	.9	1.0	1.2	1	4
4	1.25	.8	.9	1.0	1.2	1	10
4	2	1.0	1.1	1.3	1.4	1	4
5	1.5	.9	1.0	1.2	1.3	1	12
5	2	1.0	1.2	1.3	1.4	1	9
5	3	1.2	1.3	1.5	1.7	1	4
6	2.5	1.1	1.2	1.4	1.5	1	11
6	3	1.2	1.3	1.5	1.7	1	7
7	3	1.2	1.3	1.5	1.7	1	12
7	4	1.4	1.5	1.7	1.9	1	7
8	4	1.4	1.5	1.7	1.9	1	12
8	5	1.6	1.7	1.9	2.0	1	8
10	6	1.8	1.9	2.0	2.2	1	12

Table 3-E.--H_p and slope range for discharge, velocity, and crest length, Retardance E

(SI Units)

Max. Velocity V	Discharge q	H_p L(m) 7.6	15.3	30.5	61	Slope Range Min.	Max.
m/s	m^3/s/m	m	m	m	m	pct	
0.6	0.046	0.15	0.15	0.18	0.21	1	2
.9	.046	.15	.15	.18	.21	1	9
.9	.09	.21	.21	.24	.27	1	3
1.2	.09	.21	.21	.24	.27	1	6
1.2	.116	.21	.24	.27	.31	1	5
1.5	.09	.21	.21	.24	.27	1	12
1.5	.19	.27	.31	.34	.37	1	4
1.8	.14	.24	.27	.31	.34	1	12
1.8	.19	.27	.31	.34	.37	1	7
1.8	.28	.36	.36	.40	.46	1	4
2.1	.19	.27	.31	.34	.37	1	12
2.1	.28	.36	.36	.40	.46	1	7
2.4	.28	.36	.36	.40	.46	1	10
2.4	.37	.43	.43	.46	.52	1	6
3.0	.37	.43	.43	.46	.53	1	12

Table 3-E.--H_p and slope range for discharge, velocity, and crest length, Retardance E

(English Units)

Max. Velocity V	Discharge q	H_p L(ft) 25	50	100	200	Slope Range Min.	Max.
ft/s	ft^3/s/ft	ft	ft	ft	ft	pct	
2	0.5	0.5	0.5	0.6	0.7	1	2
3	.5	.5	.5	.6	.7	1	9
3	1	.7	.7	.8	.9	1	3
4	1	.7	.7	.8	.9	1	6
4	1.25	.7	.8	.9	1.0	1	5
5	1	.7	.7	.8	.9	1	12
5	2	.9	1.0	1.1	1.2	1	4
6	1.5	.8	.9	1.0	1.1	1	12
6	2	.9	1.0	1.1	1.2	1	7
6	3	1.2	1.2	1.3	1.5	1	4
7	2	.9	1.0	1.1	1.2	1	12
7	3	1.2	1.2	1.3	1.5	1	7
8	3	1.2	1.2	1.3	1.5	1	10
8	4	1.4	1.4	1.5	1.7	1	6
10	4	1.4	1.4	1.5	1.7	1	12

TABLE 4

PERMISSIBLE VELOCITIES FOR EARTH SPILLWAYS 1/
(SI Units)

Original material excavated	Meters/second
Fine sand, non-colloidal	0.46 2/
Sandy loam, non-colloidal	0.53
Silt loam, non-colloidal	0.61
Alluvial silts, non-colloidal	0.61
Ordinary firm loam	0.76
Volcanic ash	0.76
Fine gravel	0.76
Stiff clay, very colloidal	1.14
Graded, loam to cobbles, non-colloidal	1.14
Alluvial silts, colloidal	1.14
Graded, silt to cobbles, colloidal	1.22
Coarse gravel, non-colloidal	1.22
Cobbles and shingles	1.52
Shales and hardpans	1.83

TABLE 4

PERMISSIBLE VELOCITIES FOR EARTH SPILLWAYS 1/
(English Units)

Original material excavated	Feet/second
Fine sand, non-colloidal	1.50 2/
Sandy loam, non-colloidal	1.75
Silt loam, non-colloidal	2.00
Alluvial silts, non-colloidal	2.00
Ordinary firm loam	2.50
Volcanic ash	2.50
Fine gravel	2.50
Stiff clay, very colloidal	3.75
Graded, loam to cobbles, non-colloidal	3.75
Alluvial silts, colloidal	3.75
Graded, silt to cobbles, colloidal	4.00
Coarse gravel, non-colloidal	4.00
Cobbles and shingles	5.00
Shales and hardpans	6.00

1/ From TR No. 60 Earth Dams and Reservoirs, June 1976.

2/ Values shown apply to clear water, no detritus.

Figure 1

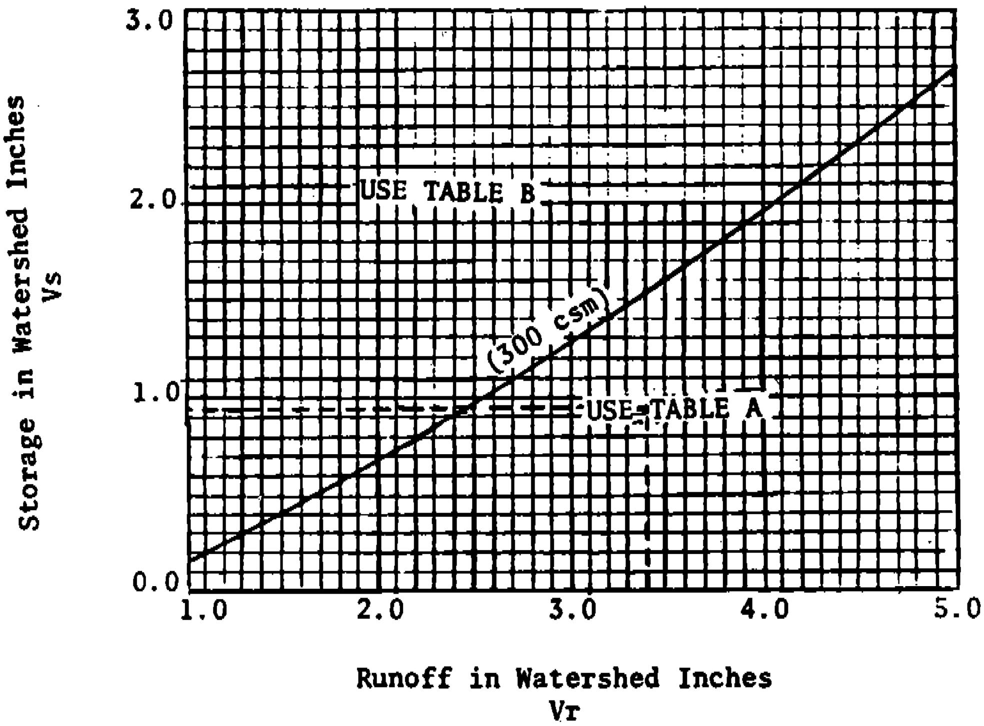


Figure 1 and Tables A and B can be used to determine the capacity of principal spillways considering temporary storage. Figure 1 is a plot of Vs versus Vr to determine which Table to use. Table A is for pipe flow structures with a discharge over 0.47 $ft^3/s/acre$ (300 csm) and Table B is for pipe flow structures with a discharge under 0.47 $ft^3/s/acre$.

Description of Terms:

Vs = Volume of temporary storage, acre-feet or in.
Vr = Volume of runoff, acre-feet or in.
Qo = Required principal spillway discharge, ft^3/s (Table A) and $ft^3/s/acre$ (Table B)
Qi = Peak flow from design storm, ft^3/s

Exhibit 11-4 Estimate of principal spillway discharge allowing for temporary storage.

Table A

$\frac{Vs}{Vr}$	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	1.00	.99	.98	.96	.95	.94	.92	.91	.90	.88
0.1	.87	.85	.84	.82	.81	.79	.78	.76	.75	.74
0.2	.70	.67	.64	.61	.58	.56	.54	.52	.50	.48
0.3	.47	.45	.44	.42	.41	.40	.39	.38	.37	.36
0.4	.35	.32	.30	.28	.26	.24	.23	.21	.20	.19
0.5	.18	.17	.16	.15	.14	.13	.12	.12	.11	.11
0.6	.10	.10	.09	.09	.08	.08	.07	.07	.07	.07
0.7	.06	.06	.06	.06	.05	.05	.05	.05	.04	.04
0.8	.04	.04	.04	.04	.04	.03	.03	.03	.03	.03

Table A: Values of Qo/Qi for pipe flow structures with a discharge over 0.47 $ft^3/s/acre$ (300 csm).

Example #1:

Given: Vs = 5.9 acre-feet or 0.94 in.
Vr = 21.1 acre-feet or 3.4 in.
Qi = 360 ft^3/s
D.A. = 75 acres

Find: Qo

Solution: Find the point for Vs of 0.94 in. and Vr of 3.4 in. in figure 1. Since the point is below the line, use Table A.

$$\frac{Vs}{Vr} = \frac{0.94}{3.4} = 0.28 \text{ (Vs and Vr must be in same units)}$$

$$\frac{Qo}{Qi} = 0.50 \text{ (From Table A)}$$

$$Qo = 0.50 \text{ X } Qi = 0.50 \text{ X } 360 \text{ ft}^3/\text{s} = 180 \text{ ft}^3/\text{s}$$

Table B

VALUES OF Qo IN $ft^3/s/acre$

STORAGE IN WATERSHED INCHES

Vs / Vr (RUNOFF IN WATERSHED INCHES)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4
1.0	.89	.39	.19	.10	.06																	
1.2		.62	.53	.20	.12	.08	.05	.04														
1.4			.57	.31	.21	.14	.09	.07	.05													
1.6				.57	.33	.23	.16	.11	.08	.06												
1.8					.59	.37	.25	.19	.13	.09	.06											
2.0						.64	.42	.27	.21	.14	.09	.06										
2.2							.62	.45	.32	.23	.13	.08	.05									
2.4								.65	.49	.34	.20	.12	.08	.05								
2.6										.49	.28	.17	.11	.08	.05							
2.8										.69	.41	.25	.16	.11	.08	.05						
3.0											.55	.34	.22	.15	.11	.08	.05					
3.2												.49	.31	.20	.14	.10	.08	.05				
3.4												.66	.44	.28	.19	.14	.10	.08	.05			
3.6													.56	.39	.26	.19	.14	.10	.08	.05		
3.8														.49	.34	.23	.16	.13	.10	.08	.05	
4.0														.65	.45	.31	.22	.17	.13	.09	.07	.05
4.2															.55	.41	.28	.20	.16	.12	.09	.07
4.4																.49	.36	.25	.21	.14	.12	.09
4.6																.62	.45	.33	.27	.19	.15	.12
4.8																	.55	.43	.33	.23	.19	.14
5.0																		.49	.39	.31	.23	.18

DISCHARGE VALUES TO THE LEFT OF LINE ARE TO BE USED FOR INTERPOLATION ONLY.
HOWEVER, INTERPOLATED VALUES SHOULD NOT EXCEED .47 $ft^3/s/acre$

Table B is for pipe flow structures with a discharge under 0.47 $ft^3/s/acre$ (300 csm).

Example #2:

Given: Vs = 34 acre-feet or 1.6 in.
Vr = 3.2 in.
Qi = 420 ft^3/s
D.A. = 256 acres (drainage area)

Find: Qo

Solution: Use Table B (determined from Figure 1)
Qo = 0.31 $ft^3/s/acre$ (from Table B)
= 0.31 $ft^3/s/acre$ X 256 acres = 79 ft^3/s

Natural Ground Slope %2	Hp	Retardance A Q	A V	B Q	B V	C Q	C V	D Q	D V	E Q	E V	Slope Min.	Slope Max.
pct	m	m^3/s	m/s	m^3/s	m/s	m^3/s	m/s	m^3/s	m/s	m^3/s	m/s	pct	
0.5	0.30	0.54	0.09	0.79	0.15	1.33	0.40	1.93	0.55	3.68	0.85	0.5	0.5
	.33	.59	.09	.99	.15	2.15	.46	3.06	.64	4.36	.91		
	.36	.82	.12	1.10	.18	2.75	.49	3.45	.70	5.78	.97		
	.40	1.02	.12	1.50	.18	3.54	.60	5.35	.76	7.08	1.04		
	.46	1.73	.12	2.46	.33	5.95	.67	8.24	.88	11.13	1.16		
	.55	2.29	.15	5.30	.55	10.87	.88	12.85	1.07	18.43	1.37		
	.61	3.11	.15	8.10	.64	14.84	1.01	21.21	1.16	24.35	1.46		
1	0.30	0.28	0.12	0.45	0.15	0.88	0.61	1.27	0.79	1.81	1.04	1	1
	.33	.35	.12	.51	.18	1.42	.70	1.78	.85	2.50	1.13		
	.36	.42	.15	.59	.24	1.76	.76	2.21	.95	2.80	1.22		
	.40	.62	.18	1.10	.30	2.43	.82	3.23	1.04	3.94	1.31		
	.46	1.13	.21	2.12	.55	3.77	.95	5.27	1.22	6.17	1.55		
	.55	1.58	.24	3.57	.70	7.93	1.16	8.38	1.37				
	.61	2.78	.33	5.21	.85	9.29	1.31	11.02	1.52				
	.76	4.84	.76	13.36	1.25	19.26	1.65						
2	0.30	0.17	0.15	0.25	0.24	0.51	0.76	0.76	1.01	1.12	1.28	1	2
	.33	.20	.21	.40	.30	.82	.85	1.10	1.10	1.42	1.37		
	.36	.26	.24	.54	.34	1.13	.94	1.44	1.19	1.81	1.49		
	.40	.37	.27	.74	.49	1.42	1.04	1.98	1.31	2.41	1.61		
	.46	.59	.30	1.10	.61	1.98	1.19	3.09	1.55	3.60	1.92		
	.55	.74	.34	2.09	.76	3.57	1.46	5.49	1.80				
	.61	1.47	.40	3.14	.98	5.38	1.65	6.48	1.95				
	.76	2.49	.85	6.74	1.58	9.60	2.07						
3	0.30	0.11	0.21	0.20	0.24	0.43	0.85	0.59	1.13	0.79	1.46	1	3
	.33	.14	.24	.28	.27	.68	.97	.88	1.22	1.08	1.58		
	.36	.20	.27	.40	.33	.93	1.10	1.16	1.34	1.39	1.71		
	.40	.28	.30	.56	.46	1.19	1.16	1.61	1.46	1.90	1.86		
	.46	.45	.37	.96	.85	1.76	1.34	2.52	1.74	2.94	2.19		
	.55	.65	.40	1.61	.91	3.17	1.68	4.05	2.04				
	.61	1.10	.46	2.29	1.13	4.62	1.89	5.49	2.19				
	.76	2.41	.95	6.00	1.83	8.50	2.38						
4	0.30	0.17	0.30	0.31	0.43	0.71	1.19	0.88	1.46	1.08	1.86	1	4
	.46	.43	.40	.82	.94	1.39	1.46	1.95	1.68	2.29	2.41		
	.55	.57	.43	1.33	1.24	2.78	1.86	3.28	2.23				
	.61	.85	.49	1.84	1.43	3.94	2.04	4.56	2.38				
	.76	2.04	1.01	4.73	2.01	6.74	2.59						
5	0.46	0.37	0.43	0.65	1.01	1.08	1.59	1.56	2.04	1.78	2.56	1	5
	.55	.48	.46	1.05	1.34	2.15	1.98	2.69	2.41				
	.61	.65	.52	1.36	1.55	3.17	2.16	3.68	2.47				
	.76	1.81	1.13	4.22	2.16	5.41	2.80						

Exhibit 11-5 Discharge through natural vegetated spillways
3:1 End slope (SI Units)

Natural Ground Slope E2	Hp	Retardance A Q	A V	B Q	B V	C Q	C V	D Q	D V	E Q	E V	Slope Min.	Slope Max.
pct	ft	ft³/s	ft/s	ft³/s	ft/s	ft³/s	ft/s	ft³/s	ft/s	ft³/s	ft/s	pct	
0.5	1.0	19	0.3	28	0.5	47	1.3	68	1.8	130	2.8	0.5	0.5
	1.1	21	.3	35	.5	76	1.5	108	2.1	154	3.0		
	1.2	29	.4	39	.6	97	1.6	122	2.3	204	3.2		
	1.3	36	.4	53	.6	125	2.0	189	2.5	250	3.4		
	1.5	61	.4	87	1.1	210	2.2	291	2.9	393	3.8		
	1.8	81	.5	187	1.8	384	2.9	454	3.5	651	4.5		
	2.0	110	.5	286	2.1	524	3.3	749	3.8	860	4.8		
1	1.0	10	0.4	16	0.5	31	2.0	45	2.6	64	3.4	1	1
	1.1	13	.4	18	.6	50	2.3	63	2.8	90	3.7		
	1.2	15	.5	21	.8	62	2.5	78	3.1	99	4.0		
	1.3	22	.6	39	1.0	86	2.7	144	3.4	139	4.3		
	1.5	40	.7	75	1.8	133	3.1	186	4.0	218	5.1		
	1.8	56	.8	126	2.3	280	3.8	296	4.5				
	2.0	98	1.1	184	2.8	328	4.3	389	5.0				
	2.5	171	2.5	472	4.1	680	5.4						
2	1.0	6	0.5	9	0.8	18	2.5	27	3.3	36	4.2	1	2
	1.1	7	.7	14	1.0	29	2.8	39	3.6	50	4.5		
	1.2	9	.8	19	1.1	40	3.1	51	3.9	64	4.9		
	1.3	13	.9	26	1.6	50	3.4	70	4.3	85	5.3		
	1.5	21	1.0	39	2.0	70	3.9	109	5.1	127	6.3		
	1.8	26	1.1	74	2.5	126	4.8	194	5.9				
	2.0	52	1.3	111	3.2	190	5.4	229	6.4				
	2.5	88	2.8	238	5.2	339	6.8						
3	1.0	4	0.7	7	0.8	15	2.8	21	3.7	28	4.8	1	3
	1.1	5	.8	10	.9	24	3.2	31	4.0	38	5.2		
	1.2	7	.9	14	1.1	33	3.6	41	4.4	49	5.6		
	1.3	10	1.0	20	1.5	42	3.8	57	4.8	67	6.1		
	1.5	16	1.2	34	2.8	62	4.4	89	5.7	104	7.2		
	1.8	23	1.3	57	3.0	112	5.5	143	6.7				
	2.0	39	1.5	81	3.7	163	6.2	194	7.2				
	2.5	85	3.1	212	6.0	300	7.8						
4	1.0	6	1.0	11	1.4	25	3.9	31	4.8	38	6.1	1	4
	1.5	15	1.3	29	3.1	49	4.8	69	5.5	81	7.9		
	1.8	20	1.4	47	4.1	98	6.1	116	7.3				
	2.0	30	1.6	65	4.7	139	6.7	161	7.8				
	2.5	72	3.3	167	6.6	238	8.5						
5	1.5	13	1.4	23	3.3	38	5.2	55	6.7	63	8.4	1	5
	1.8	17	1.5	37	4.4	76	6.5	95	7.9				
	2.0	23	1.7	48	5.1	112	7.1	130	8.1				
	2.5	64	3.7	149	7.1	191	9.2						

Exhibit 11-5 Discharge through natural vegetated spillways
3:1 End slope (English Units)

Fill Height	SIDE SLOPES 2½:1 2½:1 / 2:1 3:1	2½:1 3:1 / 2:1 3½:1	3:1 3:1 / 2½:1 3½:1	3½:1 3½:1 / 3:1 4:1	4:1 4:1 / 3:1 5:1	CROWN WIDTHS 8	10	12	14	16
1.0	3	3	3	4	4	8	10	12	14	16
1.2	4	4	4	5	6	10	12	14	17	19
1.4	5	5	6	7	8	11	14	17	20	22
1.6	6	7	8	9	10	13	16	19	22	26
1.8	8	9	10	11	13	14	18	22	25	29
2.0	10	11	12	14	16	16	20	24	28	32
2.2	12	13	15	17	19	18	22	27	31	35
2.4	14	16	17	20	23	19	24	29	34	39
2.6	17	19	20	24	27	21	26	31	36	42
2.8	20	22	23	27	31	22	28	34	39	45
3.0	22	25	27	32	36	24	30	36	42	48
3.2	26	28	31	36	41	26	32	38	45	51
3.4	29	32	35	40	46	27	34	41	47	55
3.6	32	36	39	45	52	29	36	43	50	58
3.8	36	40	43	50	58	30	38	46	53	61
4.0	40	44	48	56	64	32	40	48	56	64
4.2	44	49	53	62	71	34	42	50	59	67
4.4	48	53	58	68	77	35	44	53	61	71
4.6	53	58	63	74	85	37	46	55	64	74
4.8	57	63	69	81	92	38	48	57	67	77
5.0	62	69	75	87	100	40	50	60	70	80
5.2	67	74	81	94	108	42	52	62	73	83
5.4	73	80	87	102	117	43	54	65	75	87
5.6	78	86	94	110	125	45	56	67	78	90
5.8	84	93	101	118	135	46	58	69	81	93
6.0	90	99	108	126	144	48	60	72	84	96
6.2	96	106	115	135	154	50	62	74	87	99
6.4	102	113	123	143	164	51	64	77	89	103
6.6	109	120	131	152	174	53	66	79	92	106
6.8	116	128	139	162	185	54	68	81	95	109
7.0	123	135	147	172	196	56	70	84	98	112
7.2	130	143	156	182	207	58	72	86	101	115
7.4	138	152	165	193	219	59	74	89	103	119
7.6	145	159	174	203	231	61	76	91	106	122
7.8	153	168	183	214	243	62	78	93	109	125
8.0	160	176	192	224	256	64	80	96	112	128
8.2	169	185	202	235	269	66	82	98	115	131
8.4	177	194	212	247	282	67	84	101	117	135
8.6	186	204	222	259	296	69	86	103	120	138
8.8	194	213	232	271	310	70	88	105	123	141
9.0	203	223	243	283	324	72	90	108	126	144
9.2	212	233	254	296	339	74	92	110	129	147
9.4	222	244	266	310	353	75	94	113	131	151
9.6	231	254	277	323	369	77	96	115	134	154
9.8	241	265	289	337	384	78	98	117	137	157
10.0	250	275	300	350	400	80	100	120	140	160
10.2	260	286	313	364	416		102	122	143	163
10.4	271	298	325	379	433		104	125	145	167
10.6	281	309	338	394	449		106	127	148	170
10.8	292	321	350	409	467		108	129	151	173
11.0	302	333	363	424	484		110	132	154	176
11.2	313	344	376	440	502		112	134	157	179
11.4	325	357	390	456	520		114	137	159	183
11.6	336	370	404	472	538		116	139	162	186
11.8	348	383	418	488	557		118	141	165	189
12.0	360	396	432	504	576		120	144	168	192

Exhibit 11–6 End area table for embankment sections for various side slopes and crown widths.

4–26467 Rev. 12–68

(Sheet 1 of 3)

Fill Height	SIDE SLOPES					CROWN WIDTHS				
	2½:1 2½:1	2½:1 3:1	3:1 3:1	3½:1 3½:1	4:1 4:1	8	10	12	14	16
	2:1 3:1	2:1 3½:1	2½:1 3½:1	3:1 4:1	3:1 5:1					
12.2	372	409	447	522	595		122	146	171	195
12.4	385	424	462	539	615		124	149	173	199
12.6	397	437	477	557	635		126	151	176	202
12.8	410	451	492	574	655		128	153	179	205
13.0	422	465	507	592	676		130	156	182	208
13.2	436	479	523	610	697		132	158	185	211
13.4	449	494	539	629	718		134	161	187	215
13.6	463	509	555	648	740		136	163	190	218
13.8	476	523	571	667	762		138	166	193	221
14.0	490	539	588	686	784		140	168	196	224
14.2	505	555	605	706	807		142	170	199	227
14.4	519	570	622	726	829		144	173	202	230
14.6	534	586	639	746	853		146	175	204	234
14.8	548	602	657	767	876		148	178	207	237
15.0	563	619	675	788	900		150	180	210	240
15.2	578	635	693	809	924		152	182	213	243
15.4	594	653	711	830	949		154	185	216	246
15.6	609	669	730	852	973		156	187	218	250
15.8	625	687	749	874	999		158	190	221	253
16.0	640	704	768	896	1024		160	192	224	256
16.2	656	722	787	919	1050			194	227	259
16.4	673	740	807	942	1076			197	230	262
16.6	689	758	827	965	1102			199	232	266
16.8	706	776	847	988	1129			202	235	269
17.0	723	795	867	1012	1156			204	238	272
17.2	740	814	888	1036	1183			206	241	275
17.4	757	833	909	1060	1211			209	244	278
17.6	774	852	930	1084	1239			211	246	282
17.8	792	871	951	1109	1267			214	249	285
18.0	810	891	972	1134	1296			216	252	288
18.2	828	911	994	1160	1325			218	255	291
18.4	846	931	1016	1186	1354			221	258	294
18.6	865	951	1038	1212	1384			223	260	298
18.8	884	972	1060	1238	1414			226	263	301
19.0	903	993	1083	1264	1444			228	266	304
19.2	922	1014	1106	1291	1475			230	269	307
19.4	941	1035	1129	1318	1505			233	272	310
19.6	960	1056	1152	1345	1537			235	274	314
19.8	980	1078	1176	1372	1568			238	277	317
20.0	1000	1100	1200	1400	1600			240	280	320
20.2	1020	1122	1224	1428	1632			242	283	323
20.4	1040	1144	1248	1457	1665			245	286	326
20.6	1061	1167	1273	1486	1697			247	288	330
20.8	1082	1190	1298	1515	1731			250	291	333
21.0	1103	1213	1323	1544	1764			252	294	336
21.2	1124	1236	1348	1574	1798			254	297	339
21.4	1145	1254	1374	1604	1832			257	300	342
21.6	1166	1283	1400	1634	1866			259	302	346
21.8	1188	1307	1426	1664	1901			262	305	349
22.0	1210	1331	1452	1694	1936			264	308	352
22.2	1232	1356	1479	1725	1971			266	311	355
22.4	1254	1380	1506	1756	2007			269	314	358
22.6	1277	1405	1533	1788	2043			271	316	362
22.8	1300	1430	1560	1820	2079			274	319	365
23.0	1323	1455	1587	1852	2116			276	322	368

Exhibit 11–6 End area table for embankment sections for various side slopes and crown widths

FILL HEIGHT	SIDE SLOPES					CROWN WIDTHS		
	$2\frac{1}{2}$:1 / $2\frac{1}{2}$:1	$2\frac{1}{2}$:1 / 3:1	3:1 / 3:1	$3\frac{1}{2}$:1 / $3\frac{1}{2}$:1	4:1 / 4:1	12	14	16
	2:1 / 3:1	2:1 / $3\frac{1}{2}$:1	$2\frac{1}{2}$:1 / $3\frac{1}{2}$:1	3:1 / 4:1	3:1 / 5:1			
23.2	1346	1480	1615	1884	2153	278	325	371
23.4	1369	1506	1643	1916	2190	281	328	374
23.6	1392	1532	1671	1949	2228	283	330	378
23.8	1416	1558	1699	1983	2266	286	333	381
24.0	1440	1584	1728	2016	2304	288	336	384
24.2	1464	1611	1757	2050	2343	290	339	387
24.4	1488	1637	1786	2084	2381	293	342	390
24.6	1513	1664	1815	2118	2421	295	344	394
24.8	1538	1691	1845	2153	2460	298	347	397
25.0	1563	1719	1875	2188	2500	300	350	400
25.2	1588	1746	1905	2223	2540	302	353	403
25.4	1613	1774	1935	2258	2581	305	356	406
25.6	1638	1802	1966	2294	2621	307	358	410
25.8	1664	1831	1997	2330	2663	310	361	413
26.0	1690	1859	2028	2366	2704	312	364	416
26.2	1716	1888	2059	2403	2746	314	367	419
26.4	1742	1917	2091	2439	2788	317	370	422
26.6	1769	1946	2123	2476	2830	319	372	426
26.8	1796	1975	2155	2514	2873	322	375	429
27.0	1823	2005	2187	2552	2916	324	378	432
27.2	1850	2035	2220	2589	2959	326	381	435
27.4	1877	2065	2252	2628	3003	329	384	438
27.6	1904	2095	2285	2666	3047	331	386	442
27.8	1932	2125	2319	2705	3091	334	389	445
28.0	1960	2156	2352	2744	3136	336	392	448
28.2	1988	2187	2386	2783	3181	338	395	491
28.4	2016	2218	2420	2823	3226	341	398	454
28.6	2045	2249	2454	2863	3272	343	400	458
28.8	2074	2281	2488	2903	3318	346	403	461
29.0	2103	2313	2523	2944	3364	348	406	464
29.2	2132	2345	2558	2984	3411	350	409	467
29.4	2161	2377	2593	3025	3457	353	412	470
29.6	2190	2409	2628	3067	3505	355	414	474
29.8	2220	2442	2664	3108	3552	358	417	477
30.0	2250	2475	2700	3150	3600	360	420	480

NOTE: TO FIND THE END AREA FOR ANY FILL HEIGHT ADD SQUARE FEET FOUND UNDER STAKED SIDE SLOPES TO THAT UNDER THE CROWN WIDTH USED FOR TOTAL FOR SECTION. EXAMPLE: 6.4 FILL. 3:1 FRONT AND BACK SLOPES 14' CROWN WIDTH: 123+ 89= 212 SQUARE FEET TOTAL FOR SECTION. ANY COMBINATION OF SLOPES THAT ADD TO 5, 6, OR 7 MAY BE USED. A COMBINATION OF $3\frac{1}{2}$:1 FRONT AND $2\frac{1}{2}$:1 BACK WILL GIVE THE SAME RESULTS AS 3:1 FRONT AND BACK.

Exhibit 11–6 End area table for embankment sections for various side slopes and crown widths

Pond Inflow, Q c.f.s.	Pipe Diameter inches 1/	Pond Inflow, Q c.f.s.	Pipe Diameter inches 1/
0 - 6	15	30 - 46	36
6 - 9	18	46 - 67	42
9 - 13	21	67 - 92	48
13 - 18	24	92 - 122	54
18 - 30	30	122 - 158	60

1/ Based on a free outlet and a minimum pipe slope of 1.0 percent with the water level 0.5 foot above the top of the pipe at its upstream end.

Exhibit 11-7 Diameters of pipe inlets required to discharge various rates of inflow into excavated ponds.